Volume 2:
Technology

DELPHI VI

Forecast and Analysis of the U.S. Automotive Industry Through the Year 2000

- *Marketing*
- *Technology*
- *Materials*

The University of Michigan

DELPHI VI FORECAST AND ANALYSIS OF THE U.S. AUTOMOTIVE INDUSTRY

VOLUME 2: TECHNOLOGY

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FOREWORD

INTRODUCTION

Delphi VI is a detailed analysis of forecasts by three separate panels of automotive industry executives, directors, managers, and engineers who are expert in the areas of automotive technology, materials, and marketing. These individuals were selected because they occupy positions of responsibility within the automotive industry and have strategic insight on important industry trends. In many cases they are in a position to influence these trends. This report, published in three volumes, is the sixth in a series of in-depth studies of long-range automotive trends, which began with Delphi I in 1979 and continued with Delphi II in 1981, Delphi III in 1984, Delphi IV in 1987, and Delphi V in 1989.

The Office for the Study of Automotive Transportation collects the data, analyzes, presents, and interprets the results. Since the forecasts are those of the panelists, Delphi VI is essentially the industry's own consensus forecast. These forecasts are not "crystal ball" predictions, but rather well-informed estimates, perspectives and opinions. Such forecasts present an important basis for business decisions and provide valuable strategic planning information for those involved in all areas of the North American automotive industry: manufacturers; service, component, and materials suppliers; government; labor; public utilities; and financial institutions. We believe these to be the most authoritative and dependable North American automotive forecasts available.

A key point to keep in mind with regard to the Delphi forecast is that it presents a vision of the future. It is obviously not a precise statement of the future but rather what the industry thinks the future will likely be.

THE DELPHI METHOD: GENERAL BACKGROUND

The study is based on the Delphi forecasting process. This process requires that experts consider the issues under investigation and make predictions about future developments. Developed by the Rand Corporation for the U.S. Air Force in the late 1960s, Delphi is a systematic, interactive method of forecasting based on independent inputs regarding future events from these experts.

The Delphi method is dependent upon the judgement of knowledgeable experts. This is a particular strength of this method because, in addition to quantitative factors, predictions that require policy decision are influenced by personal preferences and expectations. Delphi forecasts reflect these personal factors. The respondents whose opinions are represented in this report are often in a position to influence events and, thus, realize their forecasts come true. Even if subsequent events result in a change of direction of a particular forecast, this does not negate the utility of the Delphi. This report's primary objective is to present the direction of technological, materials, and marketing developments within the industry and analyze potential strategic importance.

PROCESS

The Delphi method utilizes repeated rounds of questioning, including feedback of earlier-round responses, to take advantage of group input while avoiding the biasing effects possible in face-to-face panel deliberations. Some of those biasing effects are discussed in this excerpt from a 1969 Rand memorandum:

> The traditional way of pooling individual opinions is by face-to-face decisions. Numerous studies by psychologists in the past two decades have demonstrated some serious difficulties with face-to-face interaction. Among the most serious are: (1) Influence, for example, by the person who talks the most. There is very little correlation between pressure of speech and knowledge. (2) Noise. By noise is not meant auditory level (although in some face-to-face situations this may be serious enough) but semantic noise. Much of the "communication" in a discussion group has to do with individual and group interest, not with problem solving. This kind of communication, although it may appear problem-oriented, is often irrelevant or biasing. (3) Group pressure for conformity. In experiments at Rand and elsewhere, it has turned out that, after face-to-face discussions, more often than not the group response is less accurate than a simple median of individual estimates without discussion (see N.C. Dalkey, The Delphi Opinion. Memo RM 5888 PR, p. 14, Rand Corp., 1969).

In the Delphi method, panelists respond anonymously, preventing the identification of a specific opinion with any individual or company. This anonymity also provides the comfort of confidentiality, allowing the panelist to freely express his or her opinion. Among other advantages, this process enables respondents to revise a previous opinion after reviewing new information submitted by other panelists. All participants are encouraged to comment on their own forecasts and on the combined panel results. The information is then furnished to the panel participants in successive iterations. This procedure

reduces the effects of personal agendas or biases and assists the panelists in remaining focused on the questions, issues, and comments at hand.

PANEL CHARACTERISTICS AND COMPOSITION

The very essence of a Delphi survey is the careful selection of expert respondents. The selection of such experts for this Delphi survey is made possible by the long-standing association between The University of Michigan faculty/staff and representatives of the automotive industry. Lists of prospective expert panelists were assembled: one each for Technology, Marketing, and Materials. Panel members were selected on the basis of the position they occupy within the automotive industry and their knowledge of the topic being surveyed. They are deeply knowledgeable and broadly experienced in the subject matter.

The names of the panel members and their replies are known only to our office and are maintained in the strictest confidence. Replies are coded to ensure anonymity. The identity of panel members is not revealed. Upon publication of the final Delphi report, all questionnaires and lists of panelists are destroyed.

The characteristics of the 227 member panels are as follows: 10% of the Technology Panel were composed of CEOs, presidents, or vice presidents; 22% were directors; 23% were managers or supervisors; 42% were engineers (chief, assistant chief, and staff); and 3% of the panel were made up of academic specialists and consulting technical-engineering specialists. The Marketing Panel was composed of 29% CEOs, presidents, or vice-presidents; 22% directors; 39% managers; 3% engineering specialists; and 7% academic and consulting marketing specialists. Among Materials panelists, 14% were CEOs, presidents and vice-presidents; 12% were directors; 51% managers and supervisors; 16% engineering specialists; and 7% academic and consulting materials specialists. Approximately 34% of the Delphi VI panelists were employed by vehicle manufacturers; 56% by components and parts suppliers; and 10% were specialists, consultants, and academics.

PRESENTATION OF DELPHI FORECASTS AND ANALYSES

Data Tables. When a question calls for a response in the form of a number, the responses are reported as the median value and the interquartile range (IQR). The median is a measure of central tendency that mathematically summarizes an array of judgmental opinions while discounting extremely high or low estimates; it is simply the middle response. The IQR is the range bounded at the low end by the 25th-percentile value, and at the high end by the 75th-percentile value. For example, in a question calling for a percentage forecast, the median answer might be 40% and the IQR 35-45%. This means that one-quarter of the respondents answered 35% or less, another one-quarter chose 45% or more, and the middle half of all responses ranged between 36% and 44%, with 40% as the middle response. That narrow interquartile range would indicate a fairly close consensus among the respondents.

In contrast, the percentage forecast for a different question might show a similar median forecast of 40%, but with an interquartile range of 20-70%, indicating less consensus and a considerable degree of uncertainty about the issue in question.

Uncovering differences of opinion is one of the major strengths of the Delphi method. Unlike other survey methods, where differences of opinion among experts are often obscured by statistical averages, the Delphi highlights such differences through the presentation of the interquartile range.

Discussion. Narrative discussions are presented, where necessary, to highlight and explain a particular set of data.

Selected Edited Comments. Selected, edited comments from the Delphi panelists are shown following each data table in order to provide some insight into the deliberative process by which panelists arrived at their forecast.

In a Delphi survey, respondents are encouraged to contribute comments to explain their forecast and to perhaps persuade other respondents to change their positions. Many of these edited comments are included. These replies may provide important information which is not evident in the numerical data. An individual panelist may have unique knowledge that planners should carefully consider. However, readers should be careful not to overemphasize a particular comment. It is possible for a well-stated contrary opinion to mislead the reader into ignoring an important majority opinion, which is accurately reflected in numerical data.

Manufacturer/Supplier Comparison. Delphi VI panelists include respondents from the North American automotive manufacturers, the major suppliers of components, parts, and materials for the industry, as well as consultants and academics. A concerted effort is made to obtain a relatively equal distribution of manufacturer and supplier panelists. Within the context of this survey, categorizations will refer simply to either Manufacturer (or for brevity in tables, OEMs--Original Equipment Manufacturers) and Suppliers.

For obvious competitive reasons, the automotive manufacturers seek to maintain a degree of secrecy regarding their design, engineering, and marketing plans. While the relationship between the manufacturer and supplier is moving toward an increasingly closer degree of cooperation and integration, a considerable element of proprietary concern remains. Additionally, the very size and complexity of the automotive industry works against optimum information transfer. Therefore, where it is considered relevant to a better understanding of or perspective on the forecast, our analyses include a comparison of the forecast from manufacturer and supplier panelists in an attempt to illustrate where significant agreements or differences exist between the opinions of these two groups.

Comparison of Panels. The three groups of Delphi panelists (Technology, Marketing, and Materials) are asked questions that specifically focus on their respective area of expertise. However, a few questions are considered common to two or more panels. For example, the fuel-price question (see TECH-1) is considered so basic that it was submitted to all three panels.

At times, the panels will give differing responses to these questions. This may reflect the makeup of a particular panel and the panelists' subjective perception of the issue in question. Where differences do exists between the panels, serious consideration should be given to whether the difference reflects the composition and proprietary interest of that particular panel or whether there exists a substantial degree of uncertainty regarding the issue in question. We try to highlight both the differences and similarities.

Trend from Previous Delphi Surveys. A single Delphi survey is a snapshot, which collects and presents the opinions and attitudes of a group of experts at a particular point in time. Some questions, in various forms, were asked in previous Delphi surveys, and thus provide trend data. The fact that forecasts for a particular question may exhibit considerable variation over the years does not diminish its relevance and importance to strategic planning, because it reflects the consensus of expert opinion at the time. These opinions and forecasts are predicated on the best information available at the time. However, market, economic, and political factors do change. Trend data can reveal the stability or volatility of a particular market, material, or technology issue. A careful analysis of trend data is an important consideration in strategic business planning decisions.

Strategic Considerations. Based on the replies to a particular question, other relevant Delphi VI forecasts, other research and studies, and OSAT's extensive interaction with the automotive industry, this report makes inferences and interpretations as to the core issues in questions and their potential impact on the industry. By no means are they exhaustive statements of critical issues, but rather points the reader might usefully consider.

TECHNOLOGY CONTENTS

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EXECUTIVE SUMMARY

To assure prosperity, even survival, beyond the 1990s, manufacturers and suppliers must address environmental and societal concerns, meet tough competition, and satisfy demanding customers. *The Delphi VI Forecast and Analysis of the U.S. Automotive Industry through the Year 2000: Technology* survey identifies the key technical trends the industry will face in the years ahead. Our research suggests that the industry will be challenged by a high rate of change in knowledge, capital availability, time, and globalization. Risks will remain substantial, and rewards—for those who succeed—will be significant. Organizations must maximize human and financial resources in order to gain the necessary profound knowledge and strategic vision. Resources must be deployed with a systems perspective to deliver maximum consumer value while providing appropriate financial return and employee support.

The Technology volume of Delphi VI is divided into ten primary sections addressing Strategic Planning Factors, Engineering and Sourcing Issues, Emerging Technology Management Issues, Materials, Body and Chassis Product Trends, Vehicle Instrumentation/Entertainment Systems, Safety Features, Powertrain/Drivetrain, Vehicle Electronics/Electrical Systems, and Aftermarket/Dealer Service.

Strategic Planning Factors. There is general consensus that emissions, fuel economy, and safety standards will become more restrictive over the next eight years. Fuel prices are expected to increase steadily, but moderately, to $1.75 per gallon by 2005. Federal and California emission regulations are forecast to stimulate demand for alternative fuel vehicles including, flexible fuel (gasoline and methanol), natural gas, propane, electric, and electric-hybrid vehicles. More than one million annual units of production are expected by 2000.

Passenger car corporate average fuel economy (CAFE) standards are forecast to reach 30 m.p.g., 33 m.p.g., and 36 m.p.g. for 1995, 2000, and 2005, respectively. The Technology panelists believe this will be a critical issue as the practically achievable domestic passenger car fleet average will reach 28.5 m.p.g., 31 m.p.g., and 35 m.p.g. for 1995, 2000, and 2005, respectively. While CAFE may represent the greatest challenge for the industry other regulatory requirements, such as safety and emissions, are expected to present formidable challenges.

Engineering and Sourcing Issues. Product development capability is a critical success factor today. However, there is growing concern that the industry may be too occupied with the reduction of product development time. The extra dollar spent in reducing product development time must yield an extra dollar of consumer value. Japanese product development times are expected to outpace U.S. manufacturers for a new platform by approximately seven months through 2000: 28 months versus 35 months. This is a closer margin than exists today.

Foreign manufacturers' engineering will continue to move to North America to be close to increasing assembly and manufacturing activities. Approximately 25% of product design and engineering for foreign manufacturers with North American production facilities is forecast to be performed in North America. This trend should facilitate local parts sourcing. The majority of Technology panelists (93%) believe that the definition of North America will expand by 2000 to include Mexico in a free trade agreement.

Emerging Technology Management Issues. Product technology will play a larger role in achieving success in total customer satisfaction, responsiveness to market demand, styling, product innovation, safety, sales and service, product performance, and corporate reputation. Each vehicle system will be affected over the next eight years by advanced materials, new engine technologies, electronic vehicle-system control, and innovative manufacturing techniques. Product innovation is expected to increase in scope, depth, and frequency. Opportunities for information sharing and technology transfer across business, academic, and national sectors are critical. Seeking these opportunities and taking advantage of them should be integrated into a corporation's technology management strategy.

Materials. CAFE and recycling regulations are expected to be important drivers of material selection. Panelists predict a CAFE standard of 27.5 m.p.g. by 1995 and 35 m.p.g. by 2000. The 35 m.p.g. standard will result in a substantial weight reduction; steel and cast iron may decrease by 12% and 18%, respectively. With the same scenario, polymers are forecast to increase by 23%; aluminum by 13%; magnesium by 60%; and powdered metals by 20%. With more restrictive CAFE standards, the value of a pound of weight saved is forecast to rise from $1.00 per pound in 1991 to $3.00 per pound in 2000.

Panelists envision material selection from a total systems and life cycle perspective: from concept through design, out of the factory, and, ultimately, back again for reuse. Design for recycling will affect all materials, including ferrous and nonferrous metals and polymers. Engineers will consider the recycling infrastructure, energy required for processing, material separation, scrap value, and alloy content in their analysis.

Body and Chassis Product Trends. The steel unitized body is expected to remain the major vehicle platform through 2000. Space-frame construction is expected to double and capture approximately 4% of the 2000 market. Electric-powered/electronically-controlled steering systems are forecast in 10% of North American passenger car production in 2000. Active four-wheel steering (either mechanical or electrically-assisted) is expected to reach 3% penetration by 2000.

While current suspension systems are forecast to dominate the market through 2000, driver-selected, semi-active, and active suspension system usage is expected to increase significantly over its small 1991 base level. Anti-lock brakes (ABS) are expected by many to reach near 100% penetration by 2000, although the median forecast is 75%. Along with dramatic ABS growth, traction control (a relatively inexpensive additional feature using the base ABS electronic circuits) is forecast in 15% of North American-produced passenger cars by 2000.

Vehicle Instrumentation/Entertainment Systems. Complete diagnostics displays (including preventive maintenance items such as transmission-fluid level, brake-pad thickness, and tire pressure) are envisioned in future driver information systems. Very modest penetration of voice-operated radio and cellular phone controls and head-up displays are forecast. New technologically-based features will be dependent on providing customer perceived value; technology for technology's sake will not sell.

Safety Features. Driver and front passenger air bags are expected to be a standard feature on North American-produced passenger cars by 2000. Although shown only in auto show concept vehicles to date, side-impact and rear-seat air bags are envisioned in some vehicles by the year 2000. Other safety features such as collision alarms and radar braking are expected to be introduced in limited numbers over the next eight years.

Powertrain/Drivetrain. More than half of today's engines are forecast to be fundamentally redesigned during the 1990s. This will require enormous human and capital resources.

Major powertrain innovations will come about through improved and increased use of electronic fuel-management systems, multi-valve engine heads, additional speed ratios for both manual and automatic transmissions, systems integration, and pre-heated catalytic converters.

Tougher CAFE standards and federal and state emissions control initiatives are expected to drive the development and commercialization of these technologies. One significant implication may be that all manufacturers may not be equally capable of developing and implementing the necessary technology. Knowledge and technology are about to take a new step and those with lesser capabilities or limited access could experience a competitive disadvantage.

Four-stroke engine designs are expected to incorporate more distributorless ignition systems, individual cylinder ignition control, and adaptive knock control by 2000. Cylinder head designs with greater than two-valves per cylinder are expected to take 35% market share by 2000. Panelists believe that variable valve timing and lift designs could capture 15% of the 2000 market.

Two-stroke gasoline engines are forecast to reach 5% market share by 2000 and 7% by 2005. Packaging, weight reduction, cost, and possible fuel economy advantages appear to be key driving forces behind the two-stroke forecasts. However, emissions control, durability, and capital investment are envisioned as major barriers to two-stroke engine development.

Vehicle Electronics/Electrical Systems. Vehicle electronic content is expected to increase from a 1991 estimate of 10% total vehicle value to 19% by 2000. Vehicles with at least one major multiplexed power system are forecast to expand from 1991 market penetration of 1% to 15% by 2000. Multiplexing will be driven by packaging constraints, reliability, and systems integration concerns. On-board diagnostics is seen as a particularly active area for future development.

Various forms of intelligent vehicle highway system (IVHS) technology are expected by 2000. The most widely forecast technology (40% in 2000) will be motorist's service information—traffic, weather, road conditions, and other updates sent to the vehicle through radio or other means. Fifteen percent of new vehicles in 2000 are expected to have guidance systems providing a link between the vehicle and roadside sensors. These systems provide positional and route information.

Aftermarket/Dealer Service. The battle will be intense between aftermarket and dealers' service operations. The aftermarket, in particular, is forecast to face increased competition due to more sophisticated electronic technology, improved component durability, and longer warranty periods that favor traditional dealer service.

I. STRATEGIC PLANNING FACTORS

TECH-1. Please estimate U.S. retail fuel prices (per gallon) for the following years. Please use constant 1990 dollars (without adjusting for inflation).

Unleaded Gasoline	Retail Price per Gallon					
	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Regular	$1.45	$1.60	$1.75	$1.30/1.50	$1.40/1.75	$1.50/2.00
Premium	1.60	1.75	2.00	1.50/1.74	1.60/2.05	1.65/2.25

DISCUSSION

Since the oil shock of 1973, the price of petroleum has remained a key factor in automotive design and marketing. Therefore, a question regarding the domestic, retail price of gasoline has been asked in all Delphi studies since 1979.

As is made evident in the current forecasts, Delphi VI Technology panelists do not anticipate a significant increase in the price of gasoline through the year 2005. The interquartile ranges for all the years surveyed are very close, indicating a high degree of consensus among the panelists.

SELECTED EDITED COMMENTS

- CAFE will be at 40 m.p.g. in ten years. In 10-15 years electric vehicles will be a small part of total sales, but will be significant in forcing gasoline prices down.
- Coming out of the Persian Gulf war, expect an energy policy to finally be established that will gradually add an energy surcharge to gas price.
- Expect continued political instability in the Middle East.
- Expect production of more reformulated gasolines to improve emissions (i.e., less sulfur, low reid vapor pressure, changes in distillation curves, and regulated detergent requirements). This will drive prices up slightly, but competition will keep prices down, therefore, no major change.
- Fuel prices are very difficult to predict given the following uncertainties: the Middle East situation, U.S. energy policy (or lack of), the Clean Air Act and its influence on reformulated gasoline, and alternate fuels.
- Fuel prices depend on economics more than supply.
- Fuel prices will remain constant based on lower consumption driven by the demise of older vehicles and significant improvements in new vehicles.
- Hopefully the country will finally adopt an energy policy.
- Inflation and added taxes will drive these prices more than supply and demand.
- Less consumption from more efficient vehicles, as well as alternate fuels, will help control gasoline prices.
- New regulations on fuel content, oxygenated blend requirements, and RVP restrictions will continue to get tighter. Increasing availability of Methyl-Tetra-Butyl-Ethanol (MTBE) and Ethyl-Tetra-Butyl-Ethanol (ETBE) will minimize price impact and octane shortage. Barring any further distractions in the Middle East, most of the price increases will come from higher federal and state taxes.
- Price will be based on politics and taxes not technical issues like cost.
- Prices likely to become increasingly volatile; the system is increasingly unstable. Production is moving toward resource limits. Cost offsets from better technology will be unable to continue to offset the deflation of the easiest and cheapest to find (and produce) resource. Between 1950 and 1990 the inflation-adjusted price of gasoline has declined.

- Taxes and supply costs will escalate mostly for encouraging fuel economy and infrastructure repair.
- The price is political. Will Congress increase gas tax, or won't it? There is no long term shortage to increase price.
- The U.S. government will finally realize that extra taxes will be required to lower gas consumption and help pay for pollution clean-up costs. These taxes will probably be levied during the last half of the decade.
- The U.S. must come to grips by taxing gasoline to high enough levels to get more conservation and help break dependence on Middle East.
- These prices do not include any added fuel or energy taxes. At this time I do not think that the U.S. political climate will allow significant increases in this type of tax, even though it could aid the country by increasing fuel economy and energy research.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in very close agreement on U.S. retail fuel prices for the years 1995 and 2000, differing no more than five cents a gallon. The upper and lower quartile ranges are also very close. However, as illustrated in the following table, the median forecasts for both regular and premium gasoline in the year 2005 varied by 25 cents between the two groups of panelists.

Unleaded Gasoline	Forecast for 2005	
	OEM	Supplier
Regular	$1.85	$1.60
Premium	2.05	1.80

COMPARISON OF FORECAST: MAT-1 and MKT-8

With the exception of the 1995 forecast (in which the Technology panel forecast $1.45 for unleaded regular versus $1.35, the Materials forecast) the projections of the two groups were either identical or within five cents of each other.

TREND FROM PREVIOUS DELPHI SURVEYS

The following tables provide price-per-gallon forecasts for the years 1995 and 2000 from three previous Delphi surveys. Dollar prices at the time of the forecasts and adjustments to 1990 dollars are shown for each forecast.

Unleaded regular gasoline	Forecast for 1995			Forecast for 2000		
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1987 Delphi IV	1989 Delphi V	1991 Delphi VI
*Price	$1.40	$1.20	$1.45	$1.75	$1.40	$1.60
** 1990 CPI adjustment	1.51	1.26	1.45	1.84	1.48	1.60

Unleaded premium gasoline	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1987 Delphi IV	1989 Delphi V
*Price	$1.20	$1.60	$1.40	$1.75
** 1990 CPI adjustment	1.26	1.60	1.48	1.75

* Dollars at time of survey

** Adjusted to 1990 Consumer Price Index (CPI)

Over the last several years, fuel prices have demonstrated a trend toward consistency and moderation. However, in 1979, Delphi panelists forecast that the price of a gallon of gasoline in 1990 would be approximately $4.29 [adjusted to 1990 consumer price index (CPI)]; and the 1981 Delphi II forecast for 1990 was $4.11 (in 1990 dollars). In 1987, the Delphi IV forecast for unleaded regular in 1990 was $1.37 (1990 dollars). The Automobile Club of America's estimate for unleaded regular in 1990 was $1.38.

STRATEGIC CONSIDERATIONS

Generally, forecasts for future gasoline prices are modestly higher than forecasts in Delphi V. However, no significant or sharp increases are anticipated by the Technology panelists. Recent events in the Middle East that failed to result in substantial increases in energy pricing appear to support a moderate, long-range forecast. Despite the popular belief that we will face short and midterm international energy uncertainty, the energy future is likely to be reasonably stable and predictable and not likely to force major dislocations in the design of future vehicles. On the other hand, policy actions such as much more stringent CAFE standards or a significant increase in fuel taxes could have a significant effect.

A series of statements from our previous forecast, Delphi V, with some updating, are worth repeating with regard to expectations of energy price stability:

1. Even with the occurrence of a major Middle East war (and the loss of supply from several key nations), real energy prices actually decreased, indicating that, at least for the foreseeable future, there is significant global petroleum supply. Furthermore, no matter how unpredictable energy-producing countries might be, in most cases petroleum still manages to find its way to markets throughout the world.
2. Increased cash-flow requirements on the part of energy-producing nations necessitate pumping increasingly larger quantities of petroleum.
3. Progress in alternative fuel technology, particularly the use of methanol and natural gas, seems to be causing concern within the major energy-producing nations that any significant disruption of petroleum supplies could accelerate the move toward alternative fuels and thereby diminish the value of their petroleum resources.
4. Continued improvement in overall fleet-fuel economy limits increases in transportation's petroleum usage.
5. Increased stability and reliance on market-oriented economies in formerly communist countries should promote world-wide political and, therefore, economic stability.

Even with this stable energy forecast in mind, it is clear that automotive engineers must be cognizant of all issues related to energy pricing and availability and be prepared for challenging surprises.

Clearly, acceleration of petroleum demand is likely as less-developed countries become increasingly affluent and needs for individual mobility expand. Furthermore, environmental concern such as global warming, disappearance of polar ozone, and other factors may require shifts in our thinking as our knowledge of environmental issues improves. Finally, and perhaps most important, our political system is fully capable of creating a worst nightmare scenario with regard to policy actions, particularly with very aggressive fuel economy or emission regulations.

Energy, its availability, and its pricing, will clearly be fundamental factors shaping the characteristics of future motor vehicles and the automotive market.

TECH-2. What do you forecast CAFE standards for passenger cars, light trucks and vans will be in 1995, 2000, and 2005?

Vehicle Type	CAFE Standards (m.p.g.)					
	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Passenger cars	30	33	36	28/30	30/35	34/40
Light trucks and vans	24	27	30	22/25	25/30	27/33

SELECTED EDITED COMMENTS

- CAFE is a poor approach. Fuel conservation should be effected through economics.
- CAFE standards will be "percent improvement" which means each manufacturer will have different numbers.
- Expect large backlash from industry and public. Unrealistic legislation that penalizes U.S. industry should be abolished.
- Light trucks and vans will eventually be treated as cars.
- The new California Air Resources Board (CARB) rules leading to zero emissions will be a major factor. A U.S. energy policy leading to 50%, 100%, 200% increases in pump prices in the above time frame would have a wondrous effect on many insoluble problems!
- These figures are, and will be, complicated by the adjustments and allowances for electric and alternate fuel vehicles.
- This is, unfortunately, more political than technical, and therefore, impossible to predict.
- U.S. CAFE standards will decrease in importance as the Japanese will be producing vehicles that will easily exceed U.S. standards. CAFE regulations may start to be based on the level of Japanese technology, thereby raising the numbers above.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists demonstrate a very good consensus regarding CAFE standards for North American-Produced Passenger Vehicles (NAPPVs) through the year 2005. Where differences occur, they are no more than one m.p.g.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

The engineering executives in our panel project significant increases in CAFE standards although not to the extent being considered in some of the most aggressive legislation. Also, as noted in the strategic considerations of the following question, the new standards are expected to be greater than the industry can achieve in a practical manner. As general industrial competitiveness concerns are raised, one would hope that we will see practicality and policy actions come closer together. Obviously, the total issue of fuel economy regulation and the industry's ability to meet it, while still satisfying the customer, will be crucial in the 1990s.

It must always be kept in mind that the value to the customer of improved fuel economy decreases as fuel economy improves. For example, if the fuel economy of a vehicle is increased from 30 to 40 miles per gallon at today's fuel prices and with today's average miles traveled for a given vehicle, a savings of only 30 cents a day is achieved. When considered against the potential degradation of attributes such as safety or general utility, it is apparent that there could be a significant disconnect between market demands and overly aggressive fuel-economy regulation.

TECH-3. **What passenger car CAFE standards can the three traditional domestic manufacturers and other full-line vehicle manufacturers reach, with reasonable effort, in 1995, 2000, and 2005? (Reasonable effort means utilizing practical technology, while avoiding substantial reduction in passenger and luggage space and excessive costs for manufacturers and suppliers.)**

Manufacturers	CAFE Standards (m.p.g.)					
	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Traditional domestic	28.5	31.0	35.0	28/30	30/33	32/36
Full-line foreign	30.0	33.0	36.0	29/32	31/35	33/40

SELECTED EDITED COMMENTS

- CAFE forecasts depend largely on what the customer will accept in the way of size reduction.
- Depends on the "size-mix" in the product line. There should and will be some consideration of and adjustment for that in CAFE.
- Full-line importers will have to sell cars also, so they have to (and do already) import more big cars.
- Should assume no downsizing.
- The big effort to meet Clean Air Act leaves limited resources to work on fuel economy.
- The big variable is vehicle size (market segment). We will see forced redistribution downward. The midsize segment will be redefined. It will be a Cavalier/Tempo-size car.
- The manufacturers' capability in terms of m.p.g. will not be tested. The relatively low cost of gasoline and the American consumers' unwillingness to drive mini-cars/econoboxes will limit the CAFE standards. The best way to improve fuel economy is to raise the gas tax to foreign levels ($2 - $3 per gallon), letting the marketplace drive the vehicle design.
- The product mix and reduced-emissions-standards vehicle will offset CAFE potential increase by 2-4 m.p.g.
- There is substantial room for vehicle downsizing which would raise the root, fuel-economy levels to 35 m.p.g.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in very close agreement regarding reasonable CAFE standards through the year 2005. Where differences occur, they are no more than one m.p.g. Similarly, the IQRs are very close, both within and between the two panels. This indicates a high degree of consensus regarding CAFE potential for both traditional domestic and full-line foreign manufacturers.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

The technology panelists anticipate continued increases in CAFE standards beyond the present 27.5 mile per gallon level, but, in general, their forecast of future standards seems to reflect continued conflict. On one hand, it suggests industry will move aggressively to enhance fuel economy, but also recognizes the significant limitations of market acceptance and the technology, capital, and human resources that may be required. On the other hand, they believe that regulation will exceed what the industry can practically achieve. The difference between practically achievable and expected, mandated standards is significant when translated into product changes. For an individual manufacturer to close the 1-1/2 or 2 m.p.g. gap can result in significant changes in the array of products produced. The data also suggests that there really is no feasible way to produce a vehicle customers will accept with 40 m.p.g. fuel economy by the year 2000. This performance level is not achievable within the practical constraints of the industry as viewed by our panelists.

Foreign manufacturers are expected to continue to have somewhat higher levels of fuel economy because of smaller average size, but the gap with the domestic manufacturers is expected to narrow significantly beyond 2000. Incidentally, U.S. manufacturers first exceeded the fuel economy performance of Japanese manufacturers vehicles on as ten mile per gallon (m.p.g./weight) and have maintained the advantage since. From any perspective, significantly tougher fuel-economy standards will be extremely difficult for the industry to achieve. For the near term, within five years, tougher standards will be essentially impossible to achieve because these products are already well defined, and the only method available would be through control of the model mix of a given manufacturer.

TECH-4. **Most experts expect passenger car fuel economy improvements by 1995, and continuing from 1995 to 2000. In your judgement, what percent of this overall improvement will come from each of the following sources?**

Fuel Economy Improvements	Percent of Total m.p.g. Improvement			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Weight (but not size) reduction through increased use of lightweight materials	20%	20%	10/25%	10/30%
Improved engine efficiency	15	15	10/23	10/20
Downsizing	10	20	10/25	10/30
Improved drivetrain efficiency (in transmission and final drive)	10	10	5/20	5/15
Improved aerodynamics	9	5	5/10	5/10
Reduced performance (lower power/weight ratio)	8	7	5/10	5/10
Improved accessory drives	5	5	3/5	3/10
Reduced tire rolling resistance	5	5	5/10	3/10

Other factors for fuel economy improvements suggested by the panelists are as follows:

Fuel Economy Improvements	Percentage of "other" responses	
	1995	2000
Improved engine specific power (hp/l)	35%	15%
Improved powertrain systems control (better matching of shift points, converter lock-ups, etc.)	30	20
Weight reduction by improved engineering	25	30
Alternate fuel rules	10	15
Electric vehicle CAFE credits	5	15

SELECTED EDITED COMMENTS

- Addition of electronic throttle coupled with 5-speed electronic transmission will occur. Lean burn technology, lower torque convertor lock-up, valve train controls, maybe two-stroke engines with above.
- Another potential area for fuel economy increase: tailoring the engine controls to maximize fuel economy for EPA testing while performing more realistically (higher power, less economy) in actual road conditions.
- More stringent emissions and safety standards will offset any weight reduction through material substitutions.
- Not much more downsizing is possible. In fact, interior volume has varied little over the years. Rather the mix of cars has gotten smaller and will continue to do so.
- Reason will prevail at least through 2000 regarding drastic CAFE increases.
- Weight reduction through use of lightweight material will likely be counterbalanced by additional weight of mandated equipment (safety, emissions, etc.) and added feature content.

■ Weight/size, powertrain efficiency, and interaction between them represents a large majority of the opportunity.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in generally close agreement regarding sources of potential passenger-car, fuel-economy improvements. The following table illustrates the areas where opinions varied by 5% or more.

Fuel Economy Improvements	OEM				Supplier			
	Median Response		Interquartile Range		Median Response		Interquartile Range	
	1995	2000	1995	2000	1995	2000	1995	2000
Improved aerodynamics	10%	7%	5/10%	5/10%	5%	5%	5/10%	5/10%
Improved engine efficiency	15	10	10/20	10/20	20	15	10/20	10/20
Reduced performance	*	5	*	4/10	10	*	5/10	*

* No significant differences.

TREND FROM PREVIOUS DELPHI SURVEYS

In the opinion of Delphi panelists, weight reduction remains as one of the most consistently considered major factors for fuel-economy improvement. This reduction in weight, however, should not be considered to represent a reduction in vehicle size. Through their comments, the panelists have clearly indicated that weight reduction would be accomplished through an increasing utilization of lightweight materials. Downsizing, which had been the leading factor in earlier Delphi forecasts (e.g., 30% for 1990 in Delphi II), steadily declined to a projection of 5% for 1995 in Delphi V. However, as both the median and IQR indicate, downsizing has again become a major consideration for fuel economy improvement.

Fuel Economy Improvements	Forecast for 1995			Forecast for 2000	
	1987 Delphi VI	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Improved engine efficiency	22%	24%	15%	25%	15%
Weight reduction	20	20	20	20	20
Improved accessory drives	15	11	10	10	5
Improved aerodynamics	11	10	9	10	5
Downsizing	5	5	10	5	20
Reduced tire rolling resistance	5	5	5	5	5

STRATEGIC CONSIDERATIONS

We have asked this question in all previous Delphi surveys. Particularly significant changes have occurred in the panel response from Delphi V to Delphi VI. In recent Delphi forecasts, the powertrain was generally regarded as the more likely source for fuel economy improvement. Perhaps with significantly, increased expectations for tougher CAFE standards and the fact that powertrain efficiency has been improved markedly in the past few years, less is expected compared to weight reduction. Downsizing has come from well down the list to a far higher position again reflecting, perhaps, new CAFE standards and limitations of many fuel economy improvement areas. In fact, downsizing and weight reduction are in much the same position we found them in the early 1980s. This response suggests significant implications for future vehicle design. We have generally observed an industry concerned with downsizing because market forces appear to have stabilized with regard to vehicle package size. We suspect industry will pursue downsizing with a degree of reluctance because of concerns with market acceptance associated with trade-offs in comfort, general utility, and safety.

Weight reduction appears to be a favored approach to improve fuel economy through the application of lighter-weight materials, better structural designs, and new technologies such as smaller and lighter two-cycle engines. There is a general sense that the industry will pursue every practical option available to improve fuel economy.

It should be noted that the interquartile range in the data is significant for a number of these improvement areas. This reflects a wide diversity of opinion among industry experts. Perhaps the most crucial question in this entire issue of improving fuel economy is how to ultimately balance regulatory forces, the marketplace, technology, and the human and financial resources of industry. With today's competitive environment, which we see continuing, it is imperative for the automotive

manufacturers and their suppliers to do everything they can to satisfy their customers. If regulation such as tougher CAFE standards requires compromising vehicle attributes in a way unacceptable to customers, significant harm could result to the industry at a time when its assets are extraordinarily stressed.

We believe that the results of the recent National Academy of Science study of vehicle fuel economy will be a crucial influence in the interpretation of technical and business factors and will ultimately have a powerful influence on the characteristics of future vehicles.

TECH-5. How would an increase in passenger car CAFE standards to 35 or 40 m.p.g. by the year 2000 affect weight reduction and downsizing?

Effects of Increased CAFE Standards	Median Response		Interquartile Range	
	35 m.p.g.	40 m.p.g.	35 m.p.g.	40 m.p.g.
Percent weight reduction	20%	30%	10/30%	20/40%
Percent downsizing	20	25	10/30	20/50

SELECTED EDITED COMMENTS

- At 35 m.p.g., a 10% weight reduction would equal 6% fuel economy improvement if powertrains are fully rematched.
- Downsizing is almost to the average American's limit of acceptability. Further downsizing would meet considerable resistance. Major gains will have to be found in improved engine, drivetrain, and tire efficiency.
- Forced weight reductions (as a last resort to attain high CAFE) will require use of aircraft grade materials with the high cost passed on to the consumer.
- It depends on what powertrains will do (i.e., control system, aluminum blocks, more plastics in engine and vehicle) and what will be practical.
- It is not practical to reduce vehicle size. There probably will be more very small cars to get the average corporate fuel economy up, and a limited supply of full-size vehicles.
- Manufacturers will resist downsizing given market/customer impact and concentrate on weight savings, engine and gearing selection. At 40 m.p.g. CAFE, downsizing will be unavoidable.
- Marketplace will define downsizing, not manufacturers.
- Most weight reduction gains will be realized to get to 35 m.p.g. After that, downsizing is the only way to get fuel economy.
- The rest of the world seems to survive well with Topaz/Cavalier/Civic-size vehicles. The United States may one day realize the wisdom of this. Vehicle taxes based on emissions (as proposed in several European countries) would also regulate the CAFE situation.
- This gets into the realm of fantasy since the safety aspects of these vehicles would approach that of a motorcycle. I cannot believe the public would allow this to happen, particularly since the large commercial trucks will not change much. The highways will become lethal.
- Weight reduction and downsizing are not mutually exclusive. Downsizing is the most effective method of weight reduction. Radical downsizing would be required; but is this 100% of the fleet? Or 30% of the weight?
- Weight reduction without downsizing (i.e., engine displacement, reduced frontal area, etc.), is not a particularly effective way to achieve major fuel-economy gains.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in complete agreement in their forecasts for percentage of weight reduction and percentage of downsizing necessitated by an increase in CAFE to 35 or 40 m.p.g. Additionally, the interquartile ranges were either identical or extremely close.

TREND FROM PREVIOUS DELPHI SURVEY

This questions was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Two of the major, vehicle characteristics implicitly associated with significant increases in CAFE standards are size and weight reduction. Both of these factors have been demonstrated to impact safety and general utility characteristics of vehicles. Smaller, lighter vehicles are generally thought to be less safe than larger and heavier vehicles. We asked panelists to assess the impact on both a 35- and 40-m.p.g., fuel-economy standard on size and weight in the year 2000. It is evident that the impact on both size and weight is dramatic with both fuel economy scenarios. There is approximately equal distribution between weight reduction and downsizing at 35 m.p.g. with these two strategies while at 40 m.p.g., slightly greater size reduction would be required relative to weight reduction. Clearly, the industry will try to maintain a broad distribution of vehicle sizes to meet the perceived market requirement. With both scenarios and expected size and weight reduction, vehicles would change rather dramatically. It must be remembered that not a single vehicle produced in the United States at the present time is capable of achieving a 40 m.p.g. fleet fuel economy on the Federal Test Cycle; consequently, the magnitude of change required to achieve this would be significant. We question the ability of industry to achieve a 40 m.p.g. fleet-average fuel economy given the financial and human resources available.

Again, we raise the issue that from a market perspective there is a very real risk with this magnitude of weight reduction and downsizing (particularly with the downsizing) that customers would, on the average, find vehicles less attractive. Assume that the industry was able to achieve tough fuel economy standards with downsizing and weight reduction but customers responded by not purchasing vehicles and by making their opinions known to Congress. It is conceivable that we could face a situation similar to the seat belt ignition interlock system mandated by Congress in 1974: Congress reversed itself after several months because of a public outcry. If this were repeated for fuel economy, the cost penalty to the industry, which would have totally revised its production, would be astronomical. Furthermore, deferral on purchases of new, fuel-efficient-cars and trucks would keep older, less-efficient vehicles on the road longer and would potentially negate any fuel-saving and emission control benefit.

TECH-6. What percentage of North American-Produced Passenger Vehicles (NAPPVs) will be produced with alternate fuel capability in 1995, 2000, and 2005?

Alternate Fuels	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Flexible or Variable Fuel (Methanol/ethanol, gasoline blends)	1.0%	6%	10%	1/3%	3/10%	6/15%
Natural Gas	0.5	2	3	0.3/1	1/2	2/5
Propane	0.5	1	2	0.1/1	1/2	1/3

DISCUSSION

Linking forecasts of NAPPV volume presented by Delphi VI Marketing panelists with the above forecasts, the Technology panelists forecast that 225,000 NAPPVs (U.S. and Canada production) will possess some type of alternate fuel capability [excluding electric vehicle (EV) and electric-hybrid vehicle (EVH)] by 1995. Given Delphi VI Marketing NAPPV volume projections for the year 2000, alternate fuel vehicles could account for up to one-million vehicles in that model year. The upper interquartile range of 23% indicates that 25% of the Technology panelists forecast that all types of alternate fuel NAPPVs could approximate 2.5-million units by the year 2005.

The responses to this question are rather straightforward. Based on this question and other Delphi VI questions (see Tech-8 and Tech-9), it is clear that alternate fuel capability for NAPPVs is inevitable before the end of this decade. It is also apparent that the alternate fuel of choice will be methanol or a methanol/gasoline blend; although propane or LNG continue to have considerable support. In all the scenarios, however, aspects of handling, distribution, and net consumer cost (supporting infrastructure and economy of scale) remain critically important issues.

SELECTED EDITED COMMENTS

- Alternate fuels will be increasingly important for environmental reasons and ethanol use will increase due to fuel cost.
- Breakthroughs for hydrogen to solve storage, efficiency, and safety problems are assumed to occur in the decade of the 1990s.
- Clean Air Act requirements will force alternate fuels.
- Early activity will be defined by California. If gas stays cheap, there will be no incentive for alternate fuels.
- Expect natural gas and propane in fleet usage. Electric usage is based on significant, battery-technology gains and assumes no abrupt changes in environmental factors.
- Financial incentives, i.e., taxing gasoline, could foster alternate fuels. Propane could be more widely used in taxi fleets as it is in Japan.
- Flexible fuel infrastructure is the easiest to put in place. Electric vehicles will gain in late 1990s as battery technology improves. Electric vehicle fleets will be the choice for testing and actual use until 2000-2005 when that technology begins to be used in non-fleet vehicles.
- Flexible fuel is to be regarded as M-85 type fuel.
- Flexible-fuel vehicles (FFV), natural gas (NG), and propane may be used in greater numbers for light trucks than for passenger cars.
- Flexible-fuel vehicles will achieve greatest success because the infrastructure to support this technology can be put in place easier than for the other options.
- I do not see anything on the horizon that will drive NG or liquid propane gas (LPG) to higher usages because there are no significant advantages to the customer.

- Introduction of FFVs will be slower than expected due to lagging infrastructure for passenger cars. Truck applications may lead the way to establishing infrastructure.
- It depends on legislative activities. None of the alternate fuels can stand on their own versus gasoline.
- Limited range between refueling is a very serious market acceptance problem with these fuels.
- Liquid natural gas (LNG) is cheap and portable.
- Low cost of gasoline will limit economic feasibility of alternate-fuel vehicles. Battery technology will improve, becoming practical in 1995-2000. Propane is unlikely to take off as an OEM system because of its relatively poor exhaust emission performance.
- Natural gas versus propane -- only one will make it. Once they start developing, the distribution system will be a big factor. Due to continued low cost of gasoline, the growth will be highly dependent on the passage of laws requiring the change.
- Natural gas versus propane -- one will become the major alternative. Early emphasis is on natural gas.
- Percentage of FFV could be very high if CAFE credits are liberal, or very low if CAFE credits are slight.
- Propane will stay only as aftermarket conversions. It will never become an OEM option.
- Production of alternate fuel capability vehicles will be much more dependent on legislated CAFE credit incentives to manufacturers, energy policy, and clean air legislation than on market demand.
- There are many safety issues with natural gas.
- There is greater use of alternate fuels outside of North America (e.g., natural-gas vehicles in New Zealand, Italy, and British Columbia; alcohol vehicles in Brazil).
- What is most important, NO_x or total CO_2? If CO_2 must be reduced, diesel engines may experience a resurgence.
- What will happen to prices and supply could be a totally capricious process driven by economic, politics, and world conflict.
- While trucks, especially fleets, will increase their use of natural gas and propane, passenger cars will not make significant use of these fuels.
- Without major government actions to artificially increase the price of gasoline (not currently likely), alternative fuels will not make a significant market penetration.

MANUFACTURER/SUPPLIER COMPARISON

Although the interquartile ranges for OEM and supplier panelists are rather broad, reflecting a wide possible range of outcomes, the OEM and supplier panelists are in close agreement on the median forecasts for alternate-fueled vehicles through the year 2005.

COMPARISON OF FORECAST: MAT-4

As illustrated in the following table, the Materials panelists were consistently higher than the Technology panelists in their forecasts for the percent of NAPPVs that will be produced with alternate fuel capability.

Alternate Fuels	Technology Panel			Materials Panel		
	1995	2000	2005	1995	2000	2005
Flexible fuels	1.0%	6%	10%	5%	10%	15%
Natural gas	0.5	2	3	1	2	4
Propane	0.5	1	2	1	2	3

TREND FROM PREVIOUS DELPHI SURVEYS

The issue of alternate fuels was addressed in Delphi III (1984). At that time the panelists were asked: "*If there is a major and continuing interruption in international petroleum supplies, rank order motor vehicle fuel alternatives in terms of likelihood of production in significant quantities.*" Methanol derived from coal or natural gas received the highest ranking from

the panelists. In Delphi IV (1987), the issue of methanol as an alternate, motor-vehicle fuel was addressed relative to its principal advantages and disadvantages from both a vehicle perspective and a fuel perspective. Although there were differences between the two Delphi questions, the panelists were in agreement that methanol from natural gas or coal was the most likely alternative fuel.

In addition, Delphi III panelists considered the commercial-volume likelihood of petroleum-like fuels derived from coal liquids to be in the moderate range, whereas Delphi IV panelists considered coal tar petroleum products to be in the low to moderate range. Ethanol, derived mainly from biomass, was considered by Delphi III panelists to be in the low range of probability. This was insightful considering the experience of Brazil's aggressive move toward ethanol-fueled vehicles and the subsequent failure of the sugar cane harvest from which the ethanol was derived. This resulted in the idling of approximately 30% of the Brazilian domestic motor-vehicle fleet.

Thirty-five percent of the Delphi V (1989) panelists considered the likelihood of vehicle utilization of methanol derived from natural gas as very high; 48% considered the likelihood as moderate. Methanol derived from coal as a NAPPV fuel source was given a very high likelihood by 33% of the Delphi V panelists and a moderate rating by 36%. Following methanol as a fuel source, natural gas received a very high likelihood rating from 22% of the panelists and a moderate ranking from 33%. This was followed by ethanol which 18% ranked very high and 42% ranked moderate. Propane was ranked very high by 17% of the panelists.

Among the primary advantages of methanol cited by Delphi IV panelists was its availability at a reasonable low cost, although this is mitigated by the lack of a corresponding infrastructure. At the present time, this results in the cost of methanol being approximately three times that of gasoline. In addition, octane enhancement, hence power enhancement, and ease of blending were also considered a major advantage of methanol.

Disadvantages of methanol, however, included the economy of volatility control, particularly with fuel storage and handling systems. The corrosive nature of methanol and, therefore, specific materials incompatibilities, were considered a major disadvantage by past Delphi panelists, as was the increased fuel consumption and decreased driving range resulting from the lower energy density of methanol. There is also the consideration of the basic hydrophilic nature (i.e., water absorption tolerance) of methanol.

For Delphi III (1984), the following question was asked: *"Assuming no major international dislocation in petroleum supply and/or price, in what year do you expect synthetic or alternative fuel will be produced in significant quantities (1 million barrel/day in the U.S.)?:* In response to that question, the median panelists forecast was "20 years or more;" the low end of the interquartile range was 1995. Obviously, the situation has changed considerably since 1984.

The growing energy concerns of the United States are reflected in the growing awareness and acceptance of alternate fuels for NAPPVs. The last four Delphi surveys reflect a general consensus that this awareness is developing sooner rather than later, and that the American automotive industry is responding proactively rather than reactively. This is an issue with a very broad impact on both fuel systems' materials and management. It is also very dependent on many external factors such as petroleum supplies, general energy availability, and, perhaps most important, government policy.

STRATEGIC CONSIDERATIONS

From an automotive industry perspective, we have several concerns associated with the movement toward alternate-fuel capability in motor vehicles. First of all, we are faced with uncertainties with regard to the human resources and capital required to develop and then produce vehicles with these capabilities. Critical skill and capital issues are of particular concern today because of increasing shortages of both on a world scale. It must be remembered that a vehicle with alternative fuel capabilities must meet all of the technical and regulatory standards, as well as customer expectations that have been established for gasoline-fueled vehicles. These standards and expectations may increase as characteristics of alternate-fuel technology become better understood. We do believe that advances in alternate fuel capability will encourage energy-producing areas of the world to use restraint in petroleum pricing and availability. Propane, since it is a petroleum derivative, will probably be very much tied to the overall petroleum situation and could move from the point today where it is in excess supply as a by-product to a supply that is constrained if propane demand rises too aggressively for motor vehicles.

A second general area of concern is customer acceptance. We believe consumers will expect parity with today's vehicles in terms of cost per mile, convenience, safety, and travel range, areas where alternate fuels come up short in the minds of customers. Benefits of alternate fuels will have to be clearly defined and public policy used to induce use.

Based on the new Clean Air Act, fleets will be particularly affected and, indeed, the auto industry is moving aggressively to develop new alternate fuels. Natural gas appears promising as a fleet vehicle fuel, particularly where operating range is defined and central, high-pressure refueling pumps may be practical.

Finally, present day spark-ignited, internal-combustion engines can be readily adapted to use alternate fuels being evaluated for future utilization; e.g. hydrogen. No fundamental technological barriers exist and current challenges should be resolvable with appropriate development. In some cases, such as with natural gas or propane, engines would be cleaner, potentially more durable, and require less maintenance. The on-board energy storage concerns are more significant and will require compromises in such factors as travel range and packaging.

Obviously, developments with alternate fuels must be followed closely by the industry. Of course, all who are engaged in powertrain and fuel system activities will be impacted, but other suppliers and service-providers will be affected as well. Still, it must be kept in mind that petroleum-based fuels are a well-known and cost efficient means to store energy and supply is not in doubt for many years to come.

TECH-7. How many electric (EV) or electric/heat engine hybrid vehicles (EVH) will be produced in North America in MY 1995, 2000, and 2005?

Vehicle Type	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Electric vehicles	5,000	40,000	200,000	2,000/10,000	20,000/1,000,000	50,000/1,000,000
Hybrid vehicles	1,000	10,000	50,000	0/1,000	5,000/20,000	15,000/200,000

SELECTED EDITED COMMENTS

- As much as Californians would like, electric vehicles will not catch on quickly.
- California voters will change current legislation as poor vehicle performance becomes apparent. Other states will follow. Breakthrough batteries could change all of this, but it is not likely to be economical.
- California will mandate EV use and will be the test bed for the technology.
- Depends strongly on EPA/CARB issues, especially emission test procedures for hybrid.
- Electric hybrids are a real sleeper. They will come on faster than previous experience would indicate.
- Electric vehicles will include hybrids which have small diesel or turbine engines to run motor/generators to extend vehicle range.
- Electric will emerge, but not on the basis of customer demand. Rather, government will dictate its evolution as an alternative.
- Hybrid technology is too costly. Redundant requirements in too many areas. Technology breakthroughs in battery performance will occur in the mid-1990s.
- Numbers totally dependant on politics. There is no reason to build any.
- Numbers will be influenced by other states adopting California standards.
- Real fuel economy will rule out electric vehicles other than U.S. niche market.
- They are coming but success will depend upon higher energy- and power-density batteries.
- Until there is a breakthrough in battery technology (in life and in energy density), electric vehicles will have limited customer appeal. Hybrids have the best match for U.S. customer requirements but will be hard to sell.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in complete agreement in their forecasts for EVs in 1995 and EHVs through 2005. However, for the year 2000, the manufacturer panelists presented a median forecast of 40,000 EVs (IQR of 20,000/100,000). The supplier panelists forecast only 5,000 for the same year (IQR of 3,000/100,000). For the year 2005, the supplier panelists give a median forecast of 250,000 EVs (IQR of 60,000/1,000,000 and the OEM panelists forecast 80,000 EVs (IQR of 50,000/500,000). These differences reflect the uncertainty of this developing market. However, given the possible upper bound of these two technologies' volumes, manufacturers and suppliers must work together to coordinate research activities and production capacity development.

COMPARISON OF FORECAST: MAT-6

The Technology and Materials panelists present dramatically differing forecasts for the production of electric and electric hybrid vehicles. As the table illustrates, the Technology panelists exhibit considerably greater enthusiasm for electric and electric hybrid vehicles than the Materials panelists. One can only assume that the very low forecasts presented by the Materials panelists is a result of their insight into the lack of development in the area of emerging battery technology and research and development. This table presents the median responses for each panel.

Vehicle Type	Technology panel			Materials panel		
	1995	2000	2005	1995	2000	2005
Electric vehicles	5,000	40,000	200,000	1,000	4,000	8,000
Hybrid vehicles	1,000	10,000	50,000	1,000	2,000	4,000

TREND FROM PREVIOUS DELPHI SURVEYS

In 1979, Delphi I panelists forecast that 600,000 electric vehicles would be produced in the U.S. in the year 1990. In Delphi II (1981) the projection for electric vehicles in 1990 dropped to 300,000 passenger cars and 45,000 light trucks and vans. It was also forecast in Delphi II that by the year 1995, 5% of U.S.-manufactured passenger cars, 3% of U.S.-manufactured light trucks, and 5% of the vans would be electric powered. For that same year the Delphi II panelists forecast that an additional 2% of U.S.-made passenger cars would be EHV.

The forecast for electric vehicles declined further in the 1983 Delphi III survey to under 10,000 passenger cars and 5,000 light trucks and vans in 1990. However, another question in the Delphi III asked: *"When will electric car, van, and light truck production get firmly started in the U.S?"* In response to this question, Delphi III panelists forecast 1990 for vans and light trucks and 1992 for passenger cars. One of the comments in Delphi III is representative of the perception of electric vehicles at that time: "Never, it is an absurd idea. Five minutes of rational thought will reveal that the basics make an electric vehicle a failure."

Based on the declining forecast and perceptions derived from that representative comment and others, a survey of electric and electric/hybrid vehicle production was not conducted in either Delphi IV or Delphi V. Because energy and environmental conditions changed we have again included EVs in our survey.

STRATEGIC CONSIDERATIONS

The role of electric and heat-engine, electric-hybrid vehicles in the future is highly uncertain, as suggested by the broad interquartile ranges. However, expectations for both vehicles have expanded significantly since our most recent Delphi forecast, although they are nowhere near the level forecast in the late 1970s. Even if the forecast of 200,000 units of electric vehicles is achieved in the year 2000, this is still less than 2% of the overall production level. There is still major concern that battery technology will not advance to the point where EVs have broad appeal. Much of this concern with battery technology is based on electrochemistry fundamentals, which appear to limit the potential of batteries to achieve levels of energy and power density that are even close to those of liquid fuels. Obviously, a key driver for electric vehicles is the California requirement for zero-emission vehicles in the latter part of this decade. Several manufacturers appear to be committed to producing electrics and we will undoubtedly see modest numbers by the middle of this decade. We believe the limited expectations are warranted by our present understanding of the technology.

Important developments in motors, controls, small engines, and other areas have been made in recent years. A hybrid, therefore, has the potential to be a very clean and efficient powerplant. The electric hybrid (heat engine in conjunction with electric motors at the wheels) may eventually be attractive and have greater long-term potential, but the pure electric vehicle will have greater acceptance in the short-term. The hybrid could prove ultimately to be the best alternative because its heat engine could increase travel range and mitigate problems with deep-cycle limitations on battery life.

As we have noted with many of the alternative engines, developments must be watched closely because of their potential overall impact on the industry. With regard to the electric and electric-hybrid vehicles, the potential for spin-off implications are substantial. Low weight is important in electric vehicles. Developments in structural design and materials that are cost effective in the near-term for electrics may prove to have potential for a broader range of vehicles over the longer-term. The electric vehicle could be a test bed for many technologies that may not be economical to pursue with conventional vehicles. Electric vehicles have the potential of having a definite primary market demand. What could be more significant, however, is the impact that the emerging technologies could have if made available to the entire vehicle market. We emphasize, therefore, that these developments need to be monitored closely.

TECH-8. **What is your view (More restrictive, Standard, Less restrictive) of the trend in U.S. federal regulatory standards over the 1992 to 2000 time frame. Also list any likely new areas of legislative activity.**

Legislative/Regulatory Activity	Percent of Panelists		
	More restrictive	Standard	Less restrictive
Vehicle emission standards*:			
Passenger car	65%	34%	1%
Light truck	81	19	0
Fuel economy standards:			
Passenger car	90	10	0
Light truck	89	10	0
Vehicle integrity/crashworthiness:			
Passenger car	55	44	1
Light truck	77	22	1
Occupant restraint/interior safety:			
Passenger car	58	41	1
Light truck	78	22	0
"Lemon Laws":			
Passenger car	36	64	0
Light truck	35	64	1
Product liability:			
Passenger car	27	67	6
Light truck	30	64	6

*Beyond new Clean Air Act provisions

In addition to the specified likely areas of legislative activity the panelists also indicate other possible legislative or regulatory activity. The following table presents these responses. The "New Areas" categories are presented as a percentage of panelists responding.

"New Areas"	Percent of Panelists
Recyclability	44%
Alternate fuel capability	16
Driver impairment/capability verification	12
Anti-theft security	8
Anti-lock brakes	8
Built-in system diagnostics	8
Collision avoidance	8

SELECTED EDITED COMMENTS

- As long as there are lawyers running this country and not scientists, the laws will become more stringent.
- California and other state regulations are likely to be more restrictive in many areas. Federal fuel-economy laws are likely to become very restrictive, especially without an effective national energy policy.
- Expect some easing of anti-trust-type legislation to allow technology development between U.S. automakers. In addition, expect more cooperation, with government sanction, between U.S. automakers and suppliers. Similarly, closer ties to banking are likely.

- Industry must develop a cooperative relationship with government at industry's initiative.
- Politicians and lobby groups will lose influence. The movement for term limitation will cause politicians to be consumer advocates.
- We are going to have to learn to live with regulators and regulations versus fighting with them.

MANUFACTURER/SUPPLIER COMPARISON

The vehicle manufacturers and automotive suppliers are in very close agreement regarding their responses to a likelihood of federal regulatory/legislative activity within the decade. Their responses varied, (with the three exceptions noted in the following table) by less than 4%. These differences, considered worth noting, nevertheless, demonstrate a good degree of consensus.

Legislative/Regulatory Activity	Manufacturers			Suppliers		
	More restrictive	Standard	Less restrictive	More restrictive	Standard	Less restrictive
Vehicle emission standards:						
Light truck	78%	22%	0%	84%	16%	0%
Occupant restraint/interior safety:						
Light truck	75	25	5	82	18	0
Product liability:						
Passenger car	28	70	7	33	63	5
Light truck	27	66	7	35	60	5

COMPARISON OF FORECAST: MKT-6 & MAT-8

In general, a significantly larger percentage of Marketing and Materials panelists expects more restrictive federal regulatory standards to affect the North American automotive industry over the 1992-2000 time frame than the Technology panelists. This is particularly evident in the areas of passenger-car emission standards, crashworthiness, and occupant safety. The table below illustrates the specific percentages across all three panels. The three panels, however, express a good consensus when addressing these issues as they relate to light trucks; all expect increased standards. There is one obvious common area of agreement, and that is the area of fuel economy (CAFE) standards. Every one of the Materials panel respondents (100%) expects to see more CAFE regulatory activity directed at both passenger cars and light trucks. This is matched by both the Technology and Marketing panelists, who gave *more restrictive* responses in the 90% plus or very high 80% range.

There are three areas of significant disagreement between the three panels regarding regulatory activity directed at passenger cars: emission standards, crashworthiness, and occupant safety. This perhaps reflects the differing perspectives of the panels. For example, Technology panelists may expect that new and emerging automotive technologies will negate the necessity for legislation to enforce possible standards. That the OEM and supplier Technology panelists exhibit a high degree of consensus in their forecasts reinforces this conjecture. The Marketing panelists, perhaps being more responsive to consumer and political considerations, expect to see some degree of legislation regardless of new technology implementation and utilization.

The observation that a majority of respondents from all three panels does not anticipate increased regulatory activity in the areas of "lemon laws" and product liability may be a reflection of confidence in the quality, reliability, and durability of NAPPVs.

Legislative/Regulatory Activity	Percent of Total Respondents					
	Technology Panel		Marketing Panel		Materials Panel	
	More restrictive	Same	More restrictive	Same	More restrictive	Same
Fuel economy standards:						
Passenger cars	90%	10%	88%	12%	100%	0%
Light trucks	89	11	92	8	100	0
Vehicle emission standards:						
Passenger cars	65	34	91	9	75	25
Light trucks	81	19	100	0	91	9
Vehicle integrity/crashworthiness:						
Passenger car	55	44	75	25	69	31
Light truck	77	22	85	15	81	19
Occupant restraint/interior safety:						
Passenger car	58	41	77	23	84	16
Light truck	78	22	83	10	91	9
"Lemon Laws":						
Passenger car	36	64	45	52	41	56
Light truck	35	64	44	53	38	59
Product liability:						
Passenger car	27	67	42	52	34	66
Light truck	30	64	43	51	37	63

TREND FROM PREVIOUS DELPHI SURVEYS

A comparison of Delphi VI forecasts with those of preceding Delphi surveys indicates a dramatic shift in the panelists' expectations for possible imposition of governmental legislative and regulatory standards directed at the U.S. automotive industry, at either the state or federal level.

In 1979 only 31% of the Technology panelists predicted a general tightening of governmental regulatory standards by 1985, and virtually none predicted that HC, CO, and NO_x emission standards would be increased by that year. Correspondingly, 17% of the Marketing/OEM and 22% of the Marketing/Supplier panelists anticipated a tightening of future government regulations by 1990; 66% of both Delphi panelists' groups expected a tempering or easing of regulations within the same time frame.

In both 1982 and 1987 surveys, a very small percentage (13% and 14% respectively) of the Technology panelists expected legislative or regulatory standards for emissions to be increased by 1990. A dramatic change occurred in 1989; 76% of the Delphi V panelists predicted an increase in passenger-car, vehicle-emission regulation and 88% forecast light truck emission standards in the 1990s. Current Delphi VI forecasts are 65% for increased passenger-car emission standards and 88% for an increase in light truck standards.

Predictions of lower CAFE/fuel economy standards, however, increased to 37% in Delphi II (1981) and remained somewhat consistent; 32% forecast less regulation in 1990s in Delphi IV (1987) and 36% in Delphi V (1989). Conversely, only 8% of Delphi IV (1987) panelists forecast an increase in CAFE legislation through the 1990s. This increased to 30% in Delphi V (1989). At that time, 58% expected a maintenance of the status quo and 12% actually expected a decrease in passenger car CAFE. This is in sharp contrast to the current Delphi, which indicates that 90% of the respondents expect some sort of governmental regulatory activity regarding CAFE in the 1990s. Only 10% forecast no change.

The Delphi III, IV, and V panelists also forecast that "lemon laws" and occupant safety would be the dominant issues driving federal and state regulatory activity in the 1990s. In those surveys, CAFE and spark-ignited-engine emission standards were near or at the bottom of the panelists' priority considerations. In the current survey, however, both CAFE and emission standards are clearly a dominant consideration.

In the current survey, 65% expect increased regulation for passenger-car-occupant safety and 87% expect a similar increase for light-truck occupant safety. This contrasts with a 36% increase for Delphi IV panelists. By 1989, the panelists increased their expectations to 83% for passenger cars and 92% for light trucks. It is clear that safety standards for light trucks will be brought up to passenger-car standards sooner rather than later.

Current forecasts for increased regulation in the area of crashworthiness have declined from the forecasts of Delphi V, although forecasts for increased regulatory activity with respect to light trucks are significantly higher than for passenger cars. There are two conclusions that can be drawn from these observations: 1) overall NAPPV quality and, therefore, vehicle integrity have increased to a point where the need for governmental intervention to insure a standard of passenger safety has correspondingly declined; and 2) the observation that there is an expectation for relatively more activity with regard to light trucks indicates that light truck standards will be brought (or regulated) up to those of standard passenger vehicles.

The same observations can be made with regard to occupant interior safety, "lemon laws," and product liability regulatory activity. Forecasts for decreased regulatory activity presented in this Delphi may be attributed to the increased quality, reliability, and durability of present NAPPVs.

Legislative/Regulatory Activity	Technology Panel: Percent of Total Respondents								
	1987 Delphi IV			1989 Delphi V			1991 Delphi VI		
	More	Same	Less	More	Same	Less	More	Same	Less
Fuel economy standards:									
Passenger cars	8%	56%	36%	30%	58%	12%	90%	10%	0%
Light truck	*	*	*	44	47	9	89	11	1
Vehicle emission standards:									
Passenger car	14	76	10	76	23	1	65	34	1
Light truck	*	*	*	88	11	1	81	19	1
Vehicle integrity/crashworthiness:									
Passenger car	*	*	*	85	15	0	55	44	1
Light truck	*	*	*	87	12	1	77	22	1
Occupant restraint/interior safety:									
Passenger car	50	44	6	83	17	0	58	41	1
"Lemon Laws":	56	38	6	61	37	3	36	63	1
Product liability:	49	40	11	51	43	6	27	67	6

* Not asked in Delphi IV.

STRATEGIC CONSIDERATIONS

Clearly, the Technology panelists in Delphi VI anticipate continued regulatory pressure in the foreseeable future across the spectrum of vehicle characteristics. In fact, some regulatory issues such as recycling are rapidly becoming more prominent than observed in past Delphi forecasts. The recycling issue is addressed in another section of this report.

A significant fraction of the panelists does not anticipate significant change in such areas as lemon laws and product liability. But there is practically no expectation of the lessening of regulation pressure in any of the areas addressed.

It is becoming increasingly evident that the decade of the 1990s is very different than the 1980s. We have a new, federal Clean Air Act, and some very strong, new, state regulations. There is a general sense that we are in a decade that is more driven by social and environmental factors than the 1980s. In fact, one could suggest that the 1980s were highly materialistic whereas the 1990s may have a greater focus on quality-of-life issues. These include, of course, factors we associate with the automobile such as traffic congestion, pollution, safety concerns, and so forth.

Also, an important trend may be developing which could lead us in a somewhat more conservative regulatory direction. Increasingly, the domestic as well as international industry is being faced with serious capital constraints and shortages of skilled human resources. These issues may, in fact, extend well beyond just the auto industry and may become important national issues in the years ahead. As we become concerned with the cost/benefit aspects of regulations, it must be recognized that there is a possibility we will see some moderation in regulatory pressure as the question is asked, "What are

the returns on society's investment in these various policies?" There has never been a time when it has been as important for the industry to think strategically with regard to these issues and develop a relationship with the policy sector that is less based on emotion and more on fact and mutual understanding. We believe industry should begin to aggressively exercise leadership on any number of inevitable issues or trends in the future, even as they follow on some uncertain issues. Generally, the leader is more able to participate in writing the rules that must ultimately be abided in the marketplace.

We would like to reiterate a comment from a past Delphi with regard to the process of globalization and the growing shortages of capital and critical skills. All major automotive markets (Japan, Europe, and the United States) are moving aggressively in terms of regulations, safety, emissions, and other areas. Europe, for example, has only recently established emission regulations and is rapidly developing "green" rules with regard to consumer products. Because of the high cost to meet practically all types of regulation, it is increasingly important to harmonize regulations and policies that influence or affect the automotive product and industry. To do otherwise would lead to excessive waste and inefficiency that we, as a world, cannot afford. Finally, current concerns with international competitiveness suggest that we should more thoroughly consider all competitive aspects of regulation. Failure to do this could further undermine North America's competitive position in the marketplace.

TECH-9. Please indicate the likelihood of federal legislation mandating or regulating the following automotive features by the year 2000.

Automotive Feature	Likely	Not Likely
Alternate fuel capability	74%	26%
Anti-lock braking systems (ABS)	54	46
Driver impairment interlocks	22	78

SELECTED EDITED COMMENTS

- ABS appears to be market driven and may not require regulation.
- ABS will effectively be standard, with or without legislation.
- Alternate fuel will be encouraged through Corporate Average Fuel Economy (CAFE) credits or fuel price incentives, not direct legislation. Performance standards could lead to mandatory ABS and interlocks, but hardware will not be legislated.
- Alternate fuels and anti-lock braking requirements are not likely because they will be supplied without legislation. ABS will approach standard equipment. Driver impairment interlocks will recall attempt to prevent starting without fastening seatbelt--one of the shortest lived safety ideas.
- Alternate fuels will not be successful in a demand market without legislation.
- Although mandating ABS is expected, industry, by satisfying the customer, will be ahead of the legislation and the regulations will just be documentation of what was done in the market. It should be mandated, but our wimp legislators will not pass anything that impacts voters. So, like required seat belt regulations, this great safety feature will not be effectively utilized.
- Cheap gas will keep alternate fuels out of the spotlight. Electric vehicles may catch on, reducing the need for alternate fuels. ABS is becoming cheaper and is accepted as a valuable safety item and will be required by 1995. Interlocks are not cost effective, drunks can still key in sequences. Remember seat belt interlocks? Americans hated them.
- Focus must remain on environmental and safety objectives. Implementation will be left to the industry (match to customer needs).
- If the industry responds to the market demand caused by increased competition, no government intervention should be necessary or expected.
- The only way to force usage of alternate fuels will involve ready availability and disincentives to use gasoline. Passive (motorized) seat belts may be legislated out even before air bags become more widely used.
- The public will not tolerate legislation that is intrusive to normal operation (e.g., seat belt interlock with ignition experience). Driver impairment interlock would be too intrusive.
- There is a high probability of alternate fuel requirements in California.

MANUFACTURER/SUPPLIER COMPARISON

There is no significant difference between the manufacturer and supplier panelists regarding alternate fuels, ABS, and driver impairment.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Several specific areas for likely regulation were suggested. There is a feeling that alternate fuel regulation is likely and in fact, in many respects it has already been created. There is a more balanced feel with regard to anti-lock braking systems (ABS) with a prevailing view that ABS will be required. In fact, this is one area where actions of the industry are considerably ahead of the government regulatory machine.

With regard to driver-impairment detection and interlocks, there is significant reluctance to suggest regulation, perhaps reflecting the complexities of dealing with the individual consumers and their rights. The diversity of opinion on this issue serves to illustrate the many complexities associated with regulation. There is no doubt that regulation does have a role in advancing vehicle characteristics that are in general support of safety, clean air, and other social issues. However, when laws begin to intrude on individual rights, the issue becomes far more complex. Indeed, many of the areas of potential government regulation foreseen may tread on some tough political ground.

II. ENGINEERING AND SOURCING ISSUES

TECH-10. What percentage of product design and engineering is, and will be, performed in North America by the traditional domestic vehicle manufacturers in the listed years? What percentage is, and will be, performed offshore (outside of North America)?

Performance Site	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
North America	80%	80%	75%	75/90%	70/85%	70/85%
Offshore	20	20	25	10/25	15/30	15/30
TOTAL	100%	100%	100%			

SELECTED EDITED COMMENTS

- As the dollar weakens, more R&D and engineering will be located in the United States.
- Offshore engineering is caused by a loss of the educational base, R&D, and technical hands-on experience in North America by graduates who want to become consultants, lawyers, brokers, etc.
- Commonality of global designs will be driving offshore sourcing. Design teams will be responsible for specific areas with designs used in multiple manufacturing locations in both U.S. and Europe.
- Cost of engineering domestically will become much more competitive.
- Domestic engineering is dependent on increasing our engineering pool. However, market forces and national attention to education will have an effect.
- Internal capability will be increased through retraining and increased hiring.
- It is hard to define "traditional domestic." I assumed that to mean "Big Three." U.S.-based design and engineering will increase in future years with influx of Japanese design based in U.S.
- Suppliers will do more product design and engineering sourcing offshore.
- The more favorable business picture in the European arena translates into larger profits there, which will be plowed back into new products. These products will be adopted by North American operations.
- There is some offset of U.S. design loss as foreign manufacturers source design here, and that will increase.
- There will be a shift in sourcing as companies, especially Ford and GM, become more globally oriented and new markets (such as Eastern Europe, USSR, and China) open up.
- There will be a significant trend at GM and Ford to keep engineering "in-house."
- There will be a turnaround by domestic manufacturers by late 1990s. They will source some design and engineering here.
- U.S. will not give up control of their vehicle designs, especially in powertrain area.
- We will find that coordination costs outweigh offshore advantages and we will bring engineering back to the U.S.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are very close in agreement regarding where product design and engineering will be performed. Where differences in the forecast do occur, they are within a 2-5% range.

TREND FROM PREVIOUS DELPHI SURVEYS

Delphi IV (1987) panelists forecast that by 1995, 75% of the product design and engineering of U.S.-owned vehicle manufacturers would be performed domestically (North America) and 25% would be performed offshore.

In 1989, Delphi V panelists gave a current estimate of U.S. OEM product design and engineering at 85% domestic and 15% offshore. This is the same current estimate provided by Delphi VI panelists for 1990. The forecasts for 1995 provided by both Delphi V and Delphi VI panelists are identical.

STRATEGIC CONSIDERATIONS

During the past few years, there has been growing interest regarding where product design and engineering will be conducted by both the traditional American manufacturers (TAMs) and the new American manufacturers (NAMs) or transplants. There is considerable consensus in the response with regard to the sourcing of engineering by the domestic manufacturers suggesting there will be a gradual increase in offshore sourcing. This is an indication of growing globalization of the industry and development of centers of capability around the world. Furthermore, it may be a result of growing recognition that we will be experiencing critical-skill shortages in the years ahead that will necessitate more offshore sourcing of engineering. While the world car concept of a few years ago may not come to pass, components and major systems may become increasingly common to many geographic areas. This may be prompted by capital constraints as well as human resource factors.

This gradual trend of moving engineering offshore gives rise to concerns that North America could gradually find its intellectual capacity to design vehicles diminished in the years ahead. The intellectual "hollowing" may or may not be a critical competitive issue depending on the path the new world takes in the years ahead. Both manufacturers and suppliers clearly must use the best technology available, wherever it is located, to remain competitive. Engineering productivity and corporate effectiveness are closely related. Better training, more effective use of computer-based technology, improved organizational structure, and other factors could lead to significant improvements in the engineering process, which could potentially diminish the need to use offshore capabilities due to skill shortages.

Engineering service companies will certainly need to think globally as they service an increasingly complex collection of customers, including manufacturers and suppliers.

TECH-11. What percentage of product design and engineering is, and will be, performed in North America in the listed years by foreign-owned vehicle manufacturers with North American production operations? What percentage is, and will be, performed offshore?

Performance Site	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
North America	15%	20%	25%	10/20%	15/30%	15/40%
Offshore	85	80	75	80/90	70/85	60/85
TOTAL	100%	100%	100%			

SELECTED EDITED COMMENTS

- A tremendous amount of process design and engineering, tool design and engineering, as well as tool fabrication occurs outside of North America.
- As globalization proceeds, these questions and the answers to them will become murkier and less important. Basic R&D and engineering tends to be done more in the "home country" of the "parent company" than does product adjustment and adaptation to local markets.
- Globalization of vehicle design will make location of original design irrelevant to sources in a market. However, political pressure and pressure to use all available talent will act to increase local engineering wherever a manufacturer has a facility.
- Japanese manufacturers will increasingly do more engineering in the United States. They will try to appear as American companies.
- North America will continue to be production oriented with design and engineering reserved for parent offshore company operations.
- Not even Honda will begin to do serious product engineering here. There will be some increase in manufacturing engineering, but not product, because of commonalty.
- Phase II of the foreign invasion is happening now. They have gone past the design studio, marketing operations, and are establishing technical centers and support facilities (e.g., test tracks in Arizona and Michigan).
- Some styling and "Americanization" will be done in United States (e.g., captive design studios in California), but the majority will still be done in Japan and to some lesser extent in Germany.
- The Japanese will not spend a penny in the United States if not forced to.
- There will be little or no movement of high pay, engineering, or management jobs to the United States. Lots of publicity, but no substance.
- Vehicles will be designed and engineered where sold more so than today.

MANUFACTURER/SUPPLIER COMPARISON

There are no significant differences between the manufacturer and supplier panelists regarding their forecasts for the percentage of product design and engineering performed domestically or offshore by transplant vehicle manufacturers.

TREND FROM PREVIOUS DELPHI SURVEYS

As illustrated in the following table, Delphi VI forecasts are in agreement with Delphi V forecasts through the year 2000. Current forecasts anticipate that in 2000, a higher percentage of product design and engineering will be sourced offshore than previously expected. Reasons for this increase are reflected in the panelists' comments.

Off-Shore Engineering	Domestic		Offshore	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Current estimate	10%	10%	90%	90%
1995	15	15	85	85
2000	25	20	75	80

STRATEGIC CONSIDERATIONS

As a complement to the prior question, the degree of domestic engineering sourcing by foreign-based manufacturers was considered. We already see significant evidence that some engineering is being done by foreign manufacturers here in North America, represented by a mini van by Nissan in a joint venture with Ford, and Honda's design of the Accord station wagon. However, over the next ten years, the bulk of the intellectual content of foreign companies is expected to remain outside of North America. There is actually a somewhat diminished expectation for North American engineering sourcing compared with Delphi V several years ago. In any event, the forecast trend, while modest, is a firm indication of the commitment on the part of the Japanese, in particular, to becoming integrated into the North American automotive scene. One obviously key issue is how far top management of foreign firms will permit intellectual control to move away from their own centers of expertise and capability. We are reasonably confident that, ultimately, competitive pressures will dictate that engineering by both the domestic and foreign manufacturers will be sourced where it can be done best at the lowest cost and in the shortest time.

TECH-12. If there is no domestic content legislation for NAPPVs, what percentage of parts, components, subassemblies, and, will the traditional domestic manufacturers source outside North America currently and in 1995, 2000, and 2005? Please use a dollar volume basis in estimating percentages.

Countries	Median Response				Interquartile Range			
	Current Est.	1995	2000	2005	Current Est.	1995	2000	2005
Japan	7%	8%	8%	8%	5/10%	5/12%	4/13%	4/15%
Korea	2	3	3	4	2/3	2/4	2/5	2/5
Western Europe	4	5	5	5	2/5	2/7	2/10	2/10
Brazil	2	2	3	4	1.5/2	2/3	3/5	3/5
Other South America (exclude Mexico)	1	1	2	2	1/2	1/2	1/3	1/4
Taiwan	1	2	2	2	1/2	1/2	2/3	2/3
ASEAN*	1	2	2	3	1/2	1/3	1/4	2/4
Eastern Europe	1	1	2	3	0/1	0.5/1	1/3	2/5
TOTAL	19%	24%	27%	31%				

*Association of South East Asian Nations

Other countries mentioned are: China, Indonesia, Singapore, and Thailand

SELECTED EDITED COMMENTS

- A strong yen and a probably weak future U.S. dollar means no probable increase in outsourcing of parts.
- Eastern Europe will be synonymous with Western Europe. Bosch, Siemens, Lucas, etc. will be sourcing from wherever is most suitable.
- Eastern Europe will supply lower-cost components mainly to Western Europe and later to the Russian industry once it gets started.
- I believe quality will become approximately equal, so the system will tend to stabilize.
- I envision less, not more, offshore sourcing of parts and subassemblies due to leveling of worldwide economics and non-value-added transportation costs.
- Mexico and ASEAN countries will be major factors by 2005.
- Mexico and South America will have biggest increase due to low dealer costs and increased quality.
- Mexico in an American Common Market will become more prominent and we should consider how to deal with them.
- On balance, not much change except for some impact from Eastern Europe.
- There will be an increasing trend to source in the United States to avoid potential legislation, as well as to take advantage of the low dollar value.
- These developing countries will get involved through pricing advantages, especially in lower technology areas.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are essentially the same.

TREND FROM PREVIOUS DELPHI SURVEYS

Delphi VI panelists forecasts for the percentage of parts, components, and subassemblies purchased outside North America by TAMs is consistent with previous Delphi forecasts. The forecast percentage of total, component outsourcing has declined from previous Delphi forecasts. In 1989, the 1995 forecast for offshore parts sourcing was 26%, and the 2000 forecast was 30%.

STRATEGIC CONSIDERATIONS

Consistent with the overall trend toward globalization, there are continued high levels of expectation for component sourcing on a worldwide basis, although the expectations for sourcing outside of North America are modestly diminished from those of the prior Delphi surveys. Obviously, there are a number of important factors that influence sourcing decisions, including trends in exchange rates, competency of North American and foreign-based supplier networks, contractual relationships with labor, movement of foreign-owned suppliers to North America, trends in joint venture relationships, adjustments in vertical integration on the part of the manufacturers as well as suppliers, trends in commodity pricing, international labor costs, and political stability or lack thereof in various areas of the world. It is clear that this is not a simple issue in any sense of the word. Competition requires, however, that successful manufacturers procure components that, in every respect, meet expectations for quality and delivery at the lowest possible cost, to ensure competitiveness of the overall product. Engineering capability will also be an important factor in this decision as manufacturers increasingly move from price to total value-based decision making. This is a volatile issue and must be watched carefully, particularly in light of today's incredibly competitive environment.

TECH-13. **If there is no domestic content legislation for NAPPVs, what percentage of parts, components, subassemblies, etc., will the North American production operations of foreign-owned vehicle manufacturers source from North America, and what percentage from outside North America by the indicated years?**

Parts Sourcing	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
North America (U.S./Canada/Mexico)	30%	40%	50%	30/40%	35/40%	40/55%
Outside of North America	70	60	50	60/70	50/65	40/60

SELECTED EDITED COMMENTS

- As all remaining suppliers become globally competitive, distribution between foreign-owned and traditional domestic manufacturers should decrease.
- Competitive pricing will end up the key decision maker as quality issues become equal.
- Costs will dictate.
- More North American sources will be used.
- North American suppliers include Japanese transplants who will continue to be favored by the Japanese OEMs.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

There are increased expectations that foreign-owned vehicle manufacturers will increase sourcing within North America. While domestic sourcing is expected to grow, panelists still expect it to remain below the 50% content level even by the year 2005. On the surface, this appears to be a somewhat disturbing trend because of the current concerns with part sourcing by foreign-owned manufacturers, which is an extraordinarily volatile issue. We personally believe that these forecasts will be exceeded by the foreign manufacturers because of the magnitude of political pressure and the dramatic improvement in the capability of the North American supply base. If the magnitude of sourcing does not increase beyond the level suggested in the survey, we believe it will be the continuing subject of public-policy discussions. Also, sourcing at the levels suggested would indicate continuing serious balance-of-payment problems with regard to vehicle parts and increased U.S./Japan trade friction.

TECH-14. What is the likelihood of a Free Trade Agreement (FTA) with Mexico within the present decade?

Likely: 93%	Unlikely: 3%	Uncertain: 4%

SELECTED EDITED COMMENTS

- The FTA is already happening and the administration will push it through.
- Mexico will get significantly more component work. Canada will be the big loser.
- The U.S. economy cannot exist alongside a depressed economy like that of Mexico. Leveling must occur.
- The success of bringing Mexico in to an FTA will spread to Central America and South America, thereby creating a north-south segmentation of global trade.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Clearly, an overwhelming percentage of panelists view a free-trade agreement with Mexico as highly likely in the years ahead. From a strategic standpoint, this suggests that all manufacturers and suppliers will have to view the entire North American region in a very different light than in the past. From an industry perspective, this means living with invisible national borders. Manufacturers and suppliers that do not take full advantage of this opportunity will undoubtedly suffer competitive consequences as a result. This is still a highly volatile issue, particularly within the labor community, because of the fear of short-term job loss. The trend, however, seems to be inevitable and is, therefore folly to resist. Furthermore, failure of the United States to take full advantage of this opportunity could leave the door open for other countries to take advantage of the situation.

TECH-15. If the United States and Mexico develop a Free Trade Agreement (FTA) similar to the U.S./Canadian FTA, what percentage of components and vehicles produced in North America will be sourced from each country? What percentage will be sourced from outside North America?

Source	Assembled Vehicles				Components			
	Median Response		Interquartile Range		Median Response		Interquartile Range	
	1995	2000	1995	2000	1995	2000	1995	2000
North American Content								
United States	60%	55%	60/65%	50/60%	60%	55%	60/60%	50/60%
Canada	10	10	10/15	10/15	10	10	10/10	10/12
Mexico	5	10	5/10	10/15	10	15	10/10	15/20
Subtotal	75	75	75/85	75/85	80	80	80/85	80/85
Non-North American Content	25	25	15/25	15/25	20	20	15/20	15/20
Total	100%	100%			100%	100%		

SELECTED EDITED COMMENTS

- Hypothetically, a free-trade agreement with Mexico is not likely within the next decade.
- Mexico will increase North American component content.
- There is a large discrepancy between domestic- and foreign-owned companies. This will diminish as the distinction blurs.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

One of the more volatile current policy issues is related to the development of a North American Free Trade Agreement, which would include Mexico, Canada, and the United States. Organized labor is intensely opposed to this policy initiative because of the fear of job losses to lower-priced labor south of the border. On the other hand, the manufacturers and most suppliers generally favor such an agreement. The response to this question suggests that the Mexican role as the source of both assembled vehicles and components is expected to increase with implementation of a free-trade agreement during the next ten years, but not at such a rate as to cause dramatic dislocations in employment. Other factors related to competitive issues and overcapacity may, indeed, be more important than Mexico as a source of job losses in the United States and Canada. Obviously, as a new-world social and economic order emerges, including a free-trade block in North America, the general environment will remain volatile and sensitive to the many dramatic changes occurring throughout the world. We are in the midst of profound change. We are in a decade in which it is imperative to look at long-range issues in addition to the short-range impact of such actions as a free-trade agreement. It would appear that the enormity of the potential market in Mexico demands that we move aggressively to minimize the negative influence of national borders to insure the full and rapid development of this entire region.

TECH-16. **It is generally reported that the new-vehicle development process is 48 to 60 months in the United States and that Japanese producers' development cycle is significantly shorter.**

TECH-16a. **Please give your expectations (in months) of future development cycles from concept through job one for the hypothetical reskinning of high- and low-volume platforms that maintain current hardpoints.**

Future Development Cycles Maintaining Current Hardpoints	Vehicle Development Time (in months)					
	Median Response			Interquartile Range		
	Current Est.	1995	2000	Current Est.	1995	2000
High-Volume Vehicle (production *more than* 50,000 units/year)						
United States	48	40	32	40/48	36/42	30/36
Japan	36	30	25	30/36	26/35	24/32
Low-Volume Vehicle (production *less than* 50,000 units/year)						
United States	40	35	30	36/48	30/38	24/33
Japan	30	26	24	24/36	22/30	20/28

SELECTED EDITED COMMENTS

- Lessons will be learned in setting up teams taken out of the mainstream.
- The actual time for development will depend on the definition of when the concept is given the go-ahead. American manufacturers seem to spend more time on concepts, styling, market research, and feedback and, therefore, have a much longer development cycle. The tooling and engineering time is being reduced through CAD/CAM, but future reductions will be limited because time-intensive portions of the cycle (concept creation, styling, market research, and feedback) will become the biggest part.
- With the full adaptation of information technology to automotive engineering and management, this cycle time should be markedly shortened. But the culture change required is likely to defer the full implementation until about the turn of the century. Then there will be marked reduction.

MANUFACTURER/SUPPLIER COMPARISON

The one minor difference of opinion between the OEM and supplier panelists regarding vehicle-development cycle time is with regard to the reskinning of high-volume vehicles in 1995. In that particular forecast the supplier panelists are of the opinion that0t 40 months will be required for reskinning of high-volume vehicles, whereas the OEM panelists expect that such reskinning will take 36 months. Otherwise, both groups are in very close agreement, with variances of less than one month.

COMPARISON OF FORECAST: MKT-21a

The Technology and Marketing panelists are in very close agreement with their median forecasts for reskinned platforms' development cycles that maintain current hardpoints. Most of their consensus forecasts are identical. There are only two forecasts that exhibit a significant difference of opinion. First, the current development time estimate for low-volume vehicle production in the United States by the Technology panelists is 40 months; the Marketing panelists estimate 44 months. Also, there are differing forecasts for high-volume, vehicle development time by the year 2000. The following table presents the differences between the Marketing and Technology panels' 2000 high-volume, vehicle development time forecast.

Low-Volume Vehicles	Product Development Time (in months) Technology vs. Marketing	
	Technology Panel	Marketing Panel
United States	32	36
Japan	25	28

Significant differences are also evident in a comparison of the upper quartile range for low-volume vehicle development time for the years 1995 and 2000.

Low-Volume Vehicles	Vehicle Development Time (in months) (upper quartile range)			
	Technology Panel		Marketing Panel	
	1995	2000	1995	2000
United States	38	33	44	40
Japan	30	28	36	32

TREND FROM PREVIOUS DELPHI SURVEYS

There are no significant differences from previous Delphi surveys.

STRATEGIC CONSIDERATIONS

The importance of an effective, high-performance, product-development process cannot be overstated. All manufacturers and suppliers throughout the world are focusing considerable attention on improving their product-development systems. It is clear that world-class capability in product development can lead to competitive advantage and less-than-world-class performance can bring disaster. There is considerable difficulty in comparing lead-time performance on an international scale because of the challenge in precisely defining when the process starts. It appears that at least some of the advantage the Japanese possess may be due to their different definition of when the clock actually begins. Of course, this is by no means a total explanation of differences. Generally, the results of our forecast suggest that the American manufacturers are steadily improving their performance with respect to the Japanese but are not expected to attain Japanese levels by the end of the decade. Of course, the Japanese are providing a moving target with continuous improvement in their process.

It should also be noted that the cost and human resources required for product development are probably proportional to the time of product development. Manufacturers and suppliers that can reduce lead time probably will experience a commensurate cost and human resource need reduction. Obviously, the advantage of being able to bring the customer new products more quickly than a competitor is a substantial financial advantage also because of the chance to improve market share.

Our panelists are slightly less optimistic about improvements in lead time for a vehicle reskinning than they were in Delphi V. The differences are, however, relatively small and may not be significant. Because of the uncertainty today with regard to lead times, we also asked panelists about today's performance and found considerable quartile variation around the 48-month level. This seems reasonable considering the relative capabilities of manufacturers and individual groups within the industry. Steady progress is made by both the Japanese and American manufacturers for both high- and low-volume vehicles. American manufacturers are expected to close the lead-time gap to approximately six to seven months by the year 2000. We realize that there may be certain difficulties associated with attempting to forecast both high- and low-volume, vehicle-lead time. We believe providing both gives useful, general insight and direction, and indeed, there may be reasonable differences between the high- and low-volumes development processes. Today, the bulk of vehicles increasingly have relatively low volumes compared with those of 20 and 30 years ago.

As we noted in our Strategic Considerations of Delphi V, if we look back a number of years we saw extraordinarily short lead times:

> In earlier days of the industry, lead time was surprisingly short. For example, the 1955 Chevrolet was brought from concept to initial production in less than two years, and this was accomplished without the aid of computers. Of course, today's vehicles are more complex and regulatory aspects are far more severe. In the future, advanced computer technology and high-performance management should permit us to move

back essentially to where we were over 30 years ago. It appears clear that we have sufficient, basic, technological capability but may not yet have the management focus or vision to execute products quickly. There is growing consensus that project teams with multidisciplinary membership and a strong leader together with a minimum of interference from top management are very helpful in streamlining the process. This is a crucial competitive issue for the industry and bears close watching in the years ahead.

During the past year, we have met with a number of key, Japanese auto executives concerning product-development trends. The general view is that the Japanese will be moderating the speed of their process as well as lengthening their product cycles because of cost and human-resource problems.

Based on our research of the world-class, product-development processes, there are a number of key features of the world-class organizations. First, they generally employ a project team that is multidisciplinary and is strongly empowered by top management. Second, there is an intense product focus and total system responsibility. Third, these organizations are adept at learning and use a database or form of corporate memory to effectively utilize information on past successes and failures. Fourth, the development of a comprehensive network with key assets outside of the team is emphasized. Fifth, they are also systems thinkers who never lose sight of the whole, even as they work on details of the project. Invention during the context of the product-development effort is to be avoided. Rather, they select validated technology "off the shelf." Sixth, a very strong market sense and look at the product not just out the door of the manufacturing operation, but through the entire life cycle is essential. Finally, a world-class, product-development system is viewed by top management as a strategic, competitive advantage.

TECH-16b. Please give your expectations (in months) of future development cycles from concept through job one for a hypothetical new platform that establishes new hardpoints.

Future Development Cycles Programs Establishing New Hardpoints	Vehicle Development Time (in months)					
	Median Response			Interquartile Range		
	Current Est.	1995	2000	Current Est.	1995	2000
High-Volume Vehicle (production *more than* 50,000 units/year)						
United States	54	48	40	48/60	40/52	36/45
Japan	42	36	42	36/48	33/42	28/38
Low-Volume Vehicle (production *less than* 50,000 units/year)						
United States	48	40	36	40/52	35/48	30/40
Japan	36	30	28	30/40	24/36	22/33

SELECTED EDITED COMMENTS

- In Japan you cannot separate research and development from production timing. In the United States today, they are usually combined.
- It is hard to compare. Much confusion comes from definition of what exists at "concept." Japanese generally have much more work done in "research."

STRATEGIC CONSIDERATIONS

This question addressed a slightly different dimension of product development in that the question applied to a total vehicle redesign, or new platform, in contrast to a reskinning utilizing previous, vehicle hard points. The results were reasonably consistent with those in Delphi V in terms of general direction, although the present day performance is viewed as being modestly better than the "current" performance of several years ago.

Steady progress is expected to the point where high-volume vehicles can be designed in 40 months by U.S. manufacturers and 36 months for low volume. The Japanese are expected to continue with their leadership position, but by the year 2000 their advantage is expected to shrink to 8 months for high-volume vehicles and 6 months for low-volume vehicles. This may, in fact, bring reasonable parity. There is emerging concern that we may be overly preoccupied with shaving every last moment of time from the process. Concerns have recently been raised in Japan and elsewhere that there are potential risks to very fast systems in that they may not provide time for appropriate validation of the products being produced. Also, there is concern that we may be becoming caught up with the idea of change for change's sake, rather than change to increase the value of the product. Also, there is a suggestion that the very fastest-paced product development may be actually more expensive, and a more intermediate performance level is optimum. We have made these comments because we believe that it is possible that we have become overly sensitive to these timing issues and perhaps should not move forward without careful analysis of all of the factors, including costs and benefits involved. The general comments for this question are similar to TECH-16a.

Finally, the role of the computer in the lead-time compression is crucial. We expect considerable increases in software capability in the next few years, which, coupled with appropriate management of this technology, should facilitate significant increases in overall engineering effectiveness, productivity and, where appropriate, shorter lead times. Also, obviously an important part of this improvement in performance will come through eliminating basic steps that have been so much a part of today's conventional processes. Waste abounds, but we must recognize that one persons waste is anothers job. Consequently, the resistance to change can be a formidable barrier unless the sense of urgency is strong enough. The competitive pressures today seem to be spanning the sense of urgency desired.

III. EMERGING TECHNOLOGY AND TECHNOLOGY MANAGEMENT ISSUES

TECH-17. **Many observers believe that world-class cost and quality are prerequisites for competing within the various vehicle segments. Many key elements will form the bases of competition in the next decade. Please rank order from 1 to 9 (with 1=most important) your estimate of the importance the traditional domestic manufacturers will assign to these elements.**

Basis of Competition: Key Elements	Ranking
Customer satisfaction	1.5
Responsiveness to market demand, lead time	3.5
Styling/Fashion	4.4
New technology/Product innovation	4.7
Safety	5.0
Sales and service	5.1
Performance	5.3
Corporate reputation/Good citizenship	7.6
Other (multiple responses):	
Fuel Economy	6.7
Price	2.7
Environmental considerations	6.5
Ride and comfort	4.0

Other single responses include: environmentally clean and totally recyclable = 6; deproliferation of parts = 4; warranty = 4; ride/comfort = 6; and environmental responsibility = 8.

SELECTED EDITED COMMENTS

- "Customer satisfaction" is too general a term, is overworked, and has become meaningless.
- All of these are important and none can be ignored or even relegated to so low a position on the priority list that they then receive ineffectual attention.
- All of these are important, and successful competitors will find a way to assign equal priority to all; they cannot be mutually exclusive.
- All of these items are linked to customer satisfaction. The company that perceives market needs (styling, performance, and others) and can package them most cost effectively in a timely manner will achieve customer satisfaction.
- Corporate reputation is important but "good citizenship" will not sell many cars.
- I do not see a major shift from being internally driven. Satisfying customers and markets is hit or miss.
- Emissions and fuel economy legislation will determine priorities in many cases.
- I agree that quality and value will be serious and I believe turnaround time (product cycle) will be the next key competitive advantage. From a product perspective, noise, vibration, and harshness will be a very high priority along with "reasonable" performance. Technology will be applied to achieve these goals.
- If you cannot hold costs and be competitive, all the other things will not be significant.
- Most consumers buy the car in their price range that "feels" the best. Perceived "bargains" (i.e., rebates), performance, and styling sell cars for companies that are known for customer satisfaction (e.g., Honda).
- My numbers relate to the values that traditional manufacturers would like others to perceive they believe. Their real unstated attitudes may be different. For instance, I believe that today's rhetoric over quality is much stronger than the actual effort.
- *Price and quality (in that order) will precede all of the above.* The middle class simply can no longer qualify for a loan, even 60-month loans.

- Quality will become a cost of entry, i.e., expected on all products. Since performance, fuel economy, etc., is already a price of entry, the buying decision will depend on styling and added perks like customer satisfaction and dealer body innovation.
- The market will be segmented. Different segments will have different rankings.
- Total customer satisfaction includes measurement of things done right especially if we eliminate malfunctions (things going wrong). Since safety and emissions can be a sales feature, industry may well lead regulations. For example, anti-lock brakes will be standard on all vehicles.

MANUFACTURER/SUPPLIER COMPARISON

In an effort to distinguish differences in opinion between OEM and supplier panelists with respect to key competitive factors, the two groups were divided in terms of percentage responding with a 1-5 ranking (1=most important) or a 6-9 ranking (9=least important). With two notable exceptions, the two groups demonstrate a high degree of unanimity.

Overall, *Corporate Reputation* ranks the lowest in estimation of competitive importance. While this factor also receives the lowest ranking from both groups of panelists, the OEM panelists give it a significantly higher cumulative ranking with 28% responding within the 1-5 range. Only 10% of the supplier panelists are within that range and all 10% ranked it a 4. *Performance* is the next overall lowest-ranked competitive element. However, the difference between the rankings of the two groups is dramatic. Only 35% of the OEM panelists rank *Performance* within the 1-5 range, whereas 74% of the supplier panelists rank *Performance* within the 1-5 range. None of the panelists in either of the two groups gives *Performance* a number one ranking.

COMPARISON OF FORECAST: MKT-11

In the following table, estimates of important competitive factors have been rank ordered to compare the Technology and Marketing panels. A ranking scale is presented to indicate the assigned degree of importance for each competitive element.

As shown in the table, there is more unanimity than disagreement between the two panels regarding key elements of competition in the next decade. *Customer Satisfaction* ranks first by both the Technology and Marketing panels, and *Corporate Reputation* ranks last by both groups. Although the rank order of the other competitive factors differed between the two panels, with the exception of *Responsiveness to Market*, the ranking scale of remaining factors is sufficiently close enough to be considered comparable.

Elements of Competition	Technology Scale	Marketing Scale
Customer satisfaction	1.5	2.2
Responsiveness to market	3.5	4.9
Styling	4.4	3.4
New technology	4.7	4.0
Safety	5.0	5.0
Sales/service	5.1	4.9
Performance	5.3	4.9
Corporate reputation	7.6	8.6
Where 1 = most important, 9 = least important.		

TREND FROM PREVIOUS DELPHI SURVEYS

Although not precisely comparable, questions addressing the key elements forming the basis of competition within the internationalized automotive industry have been asked in previous Delphi surveys. The opinion of the panelists regarding the relative degree of influence of several factors on vehicle design and competitiveness have remained generally consistent from Delphi III through Delphi VI. There are no significant differences in the rank order of Delphi VI competitive factors when compared with previous Delphi surveys.

Quality has constantly received the highest ranking. If *Customer Satisfaction* is considered synonymous with quality, it remains the predominant highest-ranking factor in the present Delphi. *Foreign Competition* was ranked second in Delphi III and IV; but because it was apparent that foreign competition, per se, would continue to be a very highly ranked factor, it was not included in either Delphi V or Delphi VI surveys.

STRATEGIC CONSIDERATIONS

We believe there is a general consensus that world-class cost and quality are, today, just entrance tickets to the competitive playing field and that other factors will determine the success or failure of an auto company and its products. Customer satisfaction, which was overwhelmingly the leading factor cited by panelists, is a rather broad and almost all-inclusive element that includes many of the factors that are identified subsequently as competitive issues. Today, providing whatever it takes to satisfy the customer is necessary to ensure long-term success. Many of the listed factors have a significant subjective component and, therefore, are difficult for manufacturers to address. Style or fashion probably includes all elements of driving satisfaction including interior and exterior styling, ride, handling, and smell that are somehow processed in the human mind to suggest that a given product is good, mediocre, or bad. Technology must not be technology for technology's sake, but rather it must provide perceived customer value. Sales and service issues, as well, are difficult to define in a highly objective manner.

Other factors are somewhat less subjective, including reducing lead time and providing customer-oriented safety features. In this question, it is important to read the individual comments because they capture some of the more elusive concepts associated with analysis of this question.

Never before has engineering a future product required the integration of effective marketing in the product development process as it does today. Successful companies must respond to the customer and, indeed, reach beyond the customer's current perceptions to deliver product and service beyond the customer's current expectations.

TECH-18. What technologies, materials, or manufacturing issues do you feel will present the most significant challenges or opportunities to the North American automotive industry in the coming decade.

This question also received a large portion of panelists' responses. Because of multiple responses, the categories represented in the following table were established for the purpose of generalization and are not meant to be exclusive. *The Representative Responses* should be considered a descriptive adjunct to the data presented as "percent of responding panelists."

Areas of challenge/opportunity	Percent Responding
Technology innovation	71%

Within this category the following areas were specified:

	Ranking
Fuel economy/CAFE	43%
Emissions	33
Alternate fuel capability	21
Electric vehicles	12
Materials issues	26
Improved manufacturing efficiency (includes flexible manufacturing and decrease in manufacturing costs)	23
General environmental issues	7
Recyclability	4
Safety	3

REPRESENTATIVE RESPONSES

- Bringing products to market quicker will require more flexible manufacturing processes and somewhat more flexible designs capable of evolving. I believe composite materials will be a major opportunity but costs must come down.
- How to provide low cost, high value vehicles? The answer will have to address all these issues but our future, as an industry, depends on the right answers. How to meet fuel economy and emissions mandated goals while providing the customers with cars they want to own.
- Meeting emissions and CAFE requirements while: 1) maintaining or improving quality; 2) maintaining a full selection of vehicle types and sizes; and 3) keeping our eye on the customer.
- Powertrain controls will dramatically change to meet CAFE and emissions needs of the 1990s putting pressure on shortage of critical engineering, continuing education, investment cost, holding down vehicle cost.
- The main challenge facing the North American producers is to bring new technology to market faster than in the past, through attrition, layoffs, etc. There are hardly enough people to coordinate existing programs, let alone improve the situation. There has to be a different incentive system to train and motivate people better than in the past. The Japanese all have casts of thousands of engineers to do the job. Our engineers are few and their ability to handle more responsibilities is limited.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

All of the various comments should be carefully noted because of the challenges as well as opportunities they present for competitive advantage in the years ahead. In a general sense, it is clear that the application of advanced technology is viewed as being important to gaining competitive advantage. Its role is likely to be far more strategic than in the past; and for

many organizations, making key breakthroughs or developing the ability to use advanced technology can be the difference between success and failure.

One important part of any company's planning process should be the development of a technical strategic plan that thoroughly and accurately considers the core competencies necessary to achieve long-term success. This plan should include a competitive analysis with regard to technology and competency. A very challenging part of the technical planning process is the benchmarking of an organization's internal technology against world class standards. Another challenge is determining who the technical leaders are in the core competencies within an organization. In very small and focused companies, this may not be a significant problem, but in large, complex organizations this is a severe challenge.

Another element related to good technical planning is the development of appropriate human resources through new hiring and proper training of present employees.

TECH-19. What new technologies are likely to emerge in the next decade that will have a significant impact on the following vehicle systems?

DISCUSSION

This is an open-ended question soliciting the forecasts of the panelists with regard to new technologies they expect to see incorporated in NAPPVs within the next decade. This particular question received a very high response rate with many multiple responses per panelist. Therefore, the data presented represents the percentage of total responding panelists for each category and will not sum to 100%. In order to present as clear a representation as possible regarding the panelists' forecasts, representative responses are presented in lieu of comments. Emerging technologies receiving less than 5% of total panelists' responses are included in the representative responses.

ENGINE

Engine	Percent Responding
Increasing use of ceramics	26%
Two-cycle engines	26
Increasing amount of electronics: sensors/control components	21
Variable valve timing and lift	17
Electric/electric-hybrid engines	14
New lightweight materials (unspecified)	12
Alternate fuel capability	10
Increasing use of diagnostics	10
Increase in multi-valve engines	7
Use of plastic engine components	5

ENGINE DISCUSSION

The ceramic engine materials and two-cycle engines received the largest percentage of panelists' responses in this particular category. The issue of engine ceramic usage is also addressed in TECH-65. The percentage of penetration of two-cycle engines through the year 2005 as well as other factors affecting two-cycle utilization, is presented in TECH-54 and TECH-55. The electronic integration of the powertrain is an essential part of a systems approach for the entire passenger vehicle. It is evident that although an expanding infrastructure and economies of scale have reduced the gross cost of electronic components, and it is expected that unit costs will continue to decrease, the percentage cost of electronics per component is increasing (see TECH-76).

DRIVETRAIN

Drivetrain	Percent Responding
Electronic transmission control	46%
Continuously variable transmission	24
5-speed automatics	14
All wheel drive (AWD)	8
T-drive configuration	8
New materials, e.g., ceramics and powdered metals	8
6-speed automatics	5
Diagnostics	2
Traction control	2

DRIVETRAIN DISCUSSION

Electronic transmission controls are considered the leading drivetrain technology expected to emerge within the next ten years. This projection is supported by the forecasts for electronic transmission controls presented in TECH-74. What is surprising is the significant percentage of panelists who believe continuously variable transmissions (CVT) will be a significant emerging technology within the next decade. This is not in accord with the forecasts presented in TECH-72, wherein the panelists forecast a rather small percentage of CVTs (2%) by the year 2000, and in TECH-47, where only 9% of the panelists expect CVTs to be a significant powertrain change in response to the Clean Air Act. While these are small percentages, the

CVT may be an important technology considering the modest increase in total powertrain performance and, therefore, a reduction in emissions and improved fuel-economy. These differences are because respondents believe that either new technological breakthroughs will enable the development of a stronger, more durable drivebelt or that the North American consumer will accept, in quantity, engines that are of a smaller displacement.

BODY

Body	Percent Responding
Structural plastics/composites	50%
New welding/fastening techniques	27
New materials (unspecified)	17
New assembly/manufacturing systems	17
New automotive glasses	13
Space frame construction	13
Aluminum material applications	7

BODY DISCUSSION

A large percentage of the panelists responding to this question expect an increasing use of structural plastics and composites. This would appear to be in somewhat of a contrast to the forecasts presented in other Delphi questions. For example, in TECH-24 and MAT-13, the opinions of the panelists indicate that various issues of recyclability may inhibit plastics/polymers/composites use. Furthermore, as presented in TECH-22 and TECH-23, the trend data from Delphi V to Delphi VI for 1995 and 2000 do not indicate an increase in the use of these materials in either automotive structural designs or exterior components.

Additional information related to welding/fastening techniques can be found in MAT-36, MAT-37, and MAT-38.

CHASSIS

Chassis	Percent Responding
Active suspension/Ride control	54%
Composites material applications	21
ABS	17
Lightweight materials (unspecified)	13
Aluminum material application	8

CHASSIS DISCUSSION

It is the opinion of the Delphi panelists that active suspension is the most likely chassis technology to emerge by the year 2000. These data should be compared with the responses to TECH-29. In response to a query regarding the percentage application of various chassis/suspension features, Delphi VI panelists forecast that active suspension (spring and damping control) penetration in NAPP cars would be 2% by 1995 and 4% by the year 2000. In Delphi V, the panelists gave similar forecasts of 2% in 1995 and 6% by the year 2000. What is of interest is that although there is not much enthusiasm for active suspension in the first half of the 1990s, there is an increased application forecast for the latter half.

In both Delphi forecasts for 1995, the IQRs are very close. The forecasts for the year 2000 from both Delphi V and Delphi VI are very broad, indicating a considerable degree of long-term of uncertainty among the panelists at the time of the survey. It may be that the consensus forecast for a rather small penetration for active suspension in NAPP cars is valid through 1995. Although the median 2000 forecast remains small, it is three times that of the 1995 forecast. Also, the Delphi VI IQR for the 2000 forecast indicates that 25% of the panelists feel that the penetration of active suspension will be 10% or more. This may be a reflection of the enthusiasm for active suspension indicated in the response to this question.

The forecast impact of a lower-cost anti-lock braking system, having a significant impact on the application of this technology within the next decade, is basically supported by the forecast presented in MKT-35. That forecast showed a systems cost (allowing a 25% penetration rate) of $500 compared with an MY 1991 estimate of $910. It is assumed that a lower cost will allow for an even greater market penetration and become a competitive factor in the purchase decision. This is excepting the possibility of government regulations requiring ABS (see TECH-34). If this occurs every manufacturer would be required to offer ABS, thus providing no individual company a competitive advantage.

The increased use of lightweight materials is also supported by TECH-20, MAT-11, and MAT-22 forecasts.

SAFETY

Safety	Percent Responding
Collision-avoidance systems	35%
Side-impact air bags	30
Rear-seat air bags	27
Anti-lock brakes	23
Traction control	10
Passive restraints	10
Energy/crash-absorbing composites	10
IVHS	10
Vision/image	7
Structural side-impact protection	7

SAFETY DISCUSSION

Other questions related to safety issues are discussed in TECH-44, TECH-45, and TECH-46.

COMFORT/CONVENIENCE

Comfort/Convenience	Percent Responding
Personalized passenger HVAC	42%
Seating technology (e.g., programmable/memory seats)	38
Audio systems (includes noise control)	34
General electronics integration for human factors	21
"Office on wheels"	17
General IVHS developments	12
Improved glass	8
Steering-hub-mounted controls	8

COMFORT/CONVENIENCE DISCUSSION

Additional questions addressing comfort/convenience factors are discussed in TECH-38, TECH-40, TECH-43, and TECH-82.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

Please see the discussion within each subsystem.

STRATEGIC CONSIDERATIONS

Little commentary is required for this question. Readers are urged to read all responses carefully because even a single, lone response may be an indicator of an important emerging technology. Many of the mentioned items are covered in separate questions. In fact, we work very hard to develop Delphi questions to address emerging technologies related to key vehicle systems.

As competition increases and the industry becomes more knowledge and technology intensive, the chance for technological risk and opportunities has increased rather dramatically.

It also seems to be increasingly important to look for new thinking, knowledge, and technology beyond traditional automotive industry sources. The opportunities for knowledge and technology transfer that cross industry, academic, and national sectors are greater than ever before. Seeking them out should be a fundamental part of an organizations technical strategy.

IV. MATERIALS

TECH-20. **Please forecast the material content, in pounds, and the total curb weight (dry, unloaded) for the average North American-produced passenger car for model years 1995 and 2000 given the indicated CAFE scenarios.**

Materials	Median Response (In pounds)			Interquartile Range (In pounds)		
	1995		2000	1995		2000
	27.5 m.p.g.	30 m.p.g.	35 m.p.g.	27.5 m.p.g.	30 m.p.g.	35 m.p.g.
STEEL						
Low Carbon Steel	1,307	1,250	1,100	1,300/1,400	1,200/1,260	1,000/1,200
HSLA* Steel	240	250	250	240/250	240/255	214/290
Stainless Steel	35	35	35	34/36	34/36	30/37
Other Steels	40	40	40	40/40	35/40	30/40
TOTAL	1,622	1,575	1,425	1,615/1,685	1,490/1,611	1,295/1,502
CAST IRON	400	380	330	400/430	350/400	275/350
ALUMINUM						
Castings	140	150	150	110/150	130/160	140/170
Wrought Aluminum	50	50	65	35/50	45/60	50/70
TOTAL	190	200	215	160/190	175/205	200/250
PLASTICS						
Unreinforced (no fiber content)	120	120	120	100/120	100/120	100/130
Reinforced (<40% fiber content)	75	90	100	75/100	80/105	80/110
Structural Reinforced Composites (>40% fiber)	40	50	70	40/60	40/60	50/80
TOTAL	235	260	290	235/250	250/290	260/320
COPPER (including electrical)	45	45	40	45/50	40/45	35/43
ZINC (including coatings)	18	18	16	18/20	15/18.5	14/18.5
MAGNESIUM	5	6	8	5/5	5/7	5/10
GLASS	85	83	80	85/87	80/85	80/82
CERAMICS	3	3	5	2/3	2/5	3/6
POWDERED METALS	25	28	30	25/26	25/30	26/25
RUBBER						
Tires (include spare)	100	100	96	100/100	95/100	90/100
All Other Rubber	20	20	20	20/25	20/25	20/20
TOTAL	120	120	116	120/135	118/132	115/125
TOTAL ALL OTHER	250	240	230	250/260	230/260	210/235
TOTAL VEHICLE	**2,998**	**2,958**	**2,785**	**2,995/3,100**	**2,762/3,014**	**2,621/2,893**

* High Strength Low Alloy

SELECTED EDITED COMMENTS

- CAFE of 30 m.p.g. in 1995 is highly unlikely. American carmakers cannot change that quickly.
- Assuming no severe CAFE requirements as weight is reduced, vehicle interior space tends to enlarge and option loading increases total weight.
- By 2000, aluminum block engines will be more prevalent.
- Expect to see more aluminum, magnesium, and composites in the future.
- Generic numbers do not reflect the reality of vehicle program specific weight issues. We will often pay more than $1.00 per pound for the marginal weight savings. That means dropping to the next test weight. Conversely, during the conceptual stage, it is often difficult to justify spending any significant money for general weight savings.
- Magnesium should come on strong and components currently made of welded steel can be converted to aluminum or magnesium castings as the automakers see the value of paying a premium for lighter weight.
- Plastics will attain much higher usage, as will other lightweight metals. I see structural usage of plastics by 2000.
- There will be a significant increase in usage of aluminum, magnesium, and structural composites in order to maintain or improve performance and improve fuel economy.
- Toxic and hazardous materials will be eliminated by 2000, like terne plate and lead.
- Use of stainless steel will be highly dependent on flexible-fuel vehicle production.
- Weight will be almost entirely CAFE driven.
- Weight of plastics depends on recyclable requirements.
- Weight reduction in total vehicle based on change in material mix (as shown above) as well as downsizing.

MANUFACTURER/SUPPLIER COMPARISON

The two panels forecasts are within 10% of each other on all material categories and total weight except for the 2000 35 m.p.g. scenario. In this scenario, manufacturers forecast less cast iron (300 pounds versus 350 pounds) and more aluminum (250 pounds versus 220 pounds) than suppliers.

COMPARISON OF FORECAST: MAT-22

The two panels are within 10% of each other on all major material categories except two for the 2000 35 m.p.g. scenario: plastics and magnesium. The Materials panel predicts a much larger dependence upon plastics forecasting 330 pounds versus the Technology panels' 290 pound forecast. Because of its small base, magnesium usage is forecast to be 25% higher by the Materials panelists 10 pounds, versus the Technology panel's expectation of eight pounds. These differences indicate the Material panel's expectation that a 35 m.p.g. average fleet will require a significantly greater usage of high strength, low weight, high value materials.

TREND FROM PREVIOUS DELPHI SURVEYS

Comparing the current survey to Delphi V (1989), the 1995 forecast total vehicle weight for a 27.5 m.p.g. scenario is within 1%. With a few exceptions, the material categorical totals are within 10% of each other. Where there are differences, the current panel estimates a much greater use of aluminum (190 pounds versus 165 pounds), copper (45 pounds versus 25 pounds), and magnesium (five pounds versus two pounds) than the previous study. Although this is not a significant change in course, there does seem to be a trend to higher cost materials in return for improved strength, weight, and other required performance. Only the 1995 27.5 m.p.g. scenario is comparable to previous forecasts.

STRATEGIC CONSIDERATIONS

In the present Delphi, we expanded the objectives of a traditional question in our survey to explore both total weight of the vehicle and material breakdown for several, future, fuel-economy scenarios. These include the present CAFE requirement of 27.5 m.p.g., 30 m.p.g. for 1995 studies and 35 m.p.g. for the year 2000. With the present CAFE of 27.5, the results were in general accordance with recent Delphi studies in terms of both material composition and overall weight, although mass is modestly lower. The forecast for steel and cast iron is slightly lower, and the forecast for plastic and aluminum is slightly higher. The quartile range is reasonably tight particularly in the near-term forecasts. The long range forecast exhibits a greater quartile spread, which is consistent with our past experience. With increasing fuel-economy requirements, panelists, as expected, predict modest weight reduction at 30 m.p.g. in 1995 and more significant weight loss for the year 2000 at the 35 m.p.g. level. Most of the weight reduction is projected to occur in steel and cast iron, but plastic and aluminum use is forecast to increase, as well as that of magnesium. However, the magnitude of change compared with the 27.5 m.p.g. scenario is relatively small. We suspect that material issues will remain highly volatile and represent one of the most significant competitive areas of the industry. Still, all of the changes suggested in this forecast tend to be more evolutionary rather than revolutionary when considered on an industry aggregate basis. Of course, specific new vehicle-design programs could feature advanced material concepts having a different material breakdown than the given average. Success of these advanced applications in terms of cost, function, and customer acceptance could be expected to drive future programs to even greater use of a non traditional material mix. Consequently, these leading edge programs must be watched closely. Examples include Saturn's thermo-plastic doors and fenders and the Audi aluminum-intensive vehicle. We also have presented summary data for the various material segments on a percentage basis, which helps give a good sense of the overall trend direction in automotive materials.

In general, the comparison with the Materials Delphi VI panel suggests that there is a high degree of correlation for the median forecast in most major material segments. Considering the differing makeup of the two panels, one representing more generally oriented technical executives, the other material specialists, the degree of consistency is really quite remarkable.

TECH-21. What is the value (in current dollars) per pound of weight saved to a vehicle manufacturer? What will it be in 1995 and 2000? (Please do not adjust for inflation.)

Median Response			Interquartile Range		
Current Value	1995	2000	Current Value	1995	2000
$1.00	$2.00	$3.00	$1.00/$3.00	$1.00/$4.00	$2.00/$6.00

SELECTED EDITED COMMENTS

- Adding cost to reduce weight will result in lost sales in many segments.
- Again, the CAFE push (including the gas guzzler tax) can radically change the value of pounds saved. Body engineers and chassis engineers seem to have a different value per pound saved.
- Dollars per pound relates only to specific vehicles within specific fleets. How much is it worth to a given OEM to keep a given vehicle below or in its weight class?
- Everyone is usually happy (supplier and OEM) if a weight savings can be made without a cost penalty. It is more myth than fact that an OEM is willing to pay a penalty for a savings in weight alone, except in extraordinary circumstances such as "severe CAFE."
- Examples of OEMs paying more for anything (regardless of weight savings or efficiency improvement) are few and far between. Improvements must be lighter and cheaper.
- The competitive battle will be to maintain the interior package while reducing weight and keeping cost of vehicles affordable to customers.
- This forecast depends on many factors: 1) is a vehicle near the upper limit of an emissions weight class? 2) fuel-economy requirements; 3) fuel-economy penalty; 4) how close a car/fleet is to the CAFE limit; 5) the market interest in fuel economy (what is the price of a gallon of gasoline); and 6) emission regulations, especially CO_2.
- Value depends on the component and how near a vehicle is to the next-lower inertia class. The use of silicon carbide (or other particles) and reinforced aluminum will cause a breakthrough in high-strength, low-weight components (hubs, suspension-arms, knuckles, and brake calipers).

MANUFACTURER/SUPPLIER COMPARISON

Although both manufacturers and suppliers exhibit a very wide interquartile range, there is no significant disagreement in their median responses.

COMPARISON OF FORECAST: MAT-11

The Technology and Materials panelists present dramatically different assessments and forecasts for the value per pound of weight saved to a vehicle manufacturer. This comparison may be considered a reflection of the differing opinions within the automotive industry regarding the value of weight saved by the materials suppliers and the manufacturers. The IQRs are also significant (see MAT-11) in that they indicate a very high degree of disagreement within the individual panels regarding material weight saving value.

Technology panel			Materials panel		
Current Value	1995	2000	Current Value	1995	2000
$1.00	$2.00	$3.00	$2.00	$2.50	$3.00

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in the two previous Delphi surveys.

STRATEGIC CONSIDERATIONS

During the early years of our Delphi forecasts, we asked this question. We omitted it from Delphi IV and V because of the model mix, size, and weight stability of most manufacturers' products. However, with serious consideration of more restrictive CAFE standards and the high rating given to weight reduction as a means to improve fuel economy, we have addressed this issue again. Presently, the value of weight savings is in the range it has been for some time, based on early Delphi results. However, with the expectation of more aggressive fuel-economy legislation, the value of a pound of weight saved is expected to escalate dramatically through the year 2000. There is also ample evidence in the comments to this question suggesting that the manufacturers will be reluctant to pay premiums for weight reduction. Clearly, this future price/value scenario suggests the potential of a major new era as far as materials are concerned and indicates that the material competition could move to the next level during the 1990s.

It is also important, we believe, to note that the value of a pound of weight saved may be very different depending on special circumstances, such as proximity to an EPA inertia weight class. Also, lower weight has value in the unsprung mass where it can improve ride and handling; and it could influence friction, and therefore smoothness, in the reciprocating mass of the engine. The rate of increase in this value during the 1990s is far greater than one would anticipate in a relatively orderly environment and gives rise to the idea that this, indeed, may be an uncertain and risky decade. Lightweight materials and design and manufacturing techniques leading to weight reduction should receive considerable attention unless, of course, the regulatory hysteria calms.

TECH-22. What is your forecast for the material mix of steel, aluminum, and plastic-reinforced composites used in frame/structural members in integral body/frame and in space-frame designs for NAPPVs in the MYs 1995 and 2000?

Material Mix	Space frame				Integral body frame			
	Median Response		Interquartile Range		Median Response		Interquartile Range	
	1995	2000	1995	2000	1995	2000	1995	2000
Steel	89%	80%	80/90%	70/85%	89%	80%	80/90%	70/85%
Aluminum	6	10	5/10	7/15	6	10	5/10	7/15
Composites	5	10	5/10	8/15	5	10	5/10	8/15

SELECTED EDITED COMMENTS

- If, as forecasted, metal tooling costs are reduced to composite levels, there is little benefit in composite structures due to increased costs and scrap management difficulties.
- Plastics research should continue to provide cheaper, lighter, and stronger materials, which will find ever-increasing use in vehicles.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in very close agreement regarding the material mix for future automotive structural applications. The only differences appear in the forecast for aluminum use in integral body/frame by the year 2000; the OEM panelists forecast 10% and the supplier panelists forecast 7%. The IQRs of the two groups correspond closely.

COMPARISON OF FORECAST: MAT-17

There are no significant differences between the Technology and Materials panelists with regard to the material mix of the integral body/frame and space frame for NAPPVs.

TREND FROM PREVIOUS DELPHI SURVEYS

As illustrated in the following table, expectations for an increasing usage of aluminum and plastic-reinforced composites in future automotive structural applications in both integral body/frames and space frames have declined since the 1987 Delphi IV. While there was an increase in the forecast in Delphi V for the utilization of composites in space frame applications by the year 2000, the current Delphi panelists express a diminished expectation. It appears that steel will remain the material of choice for structural frame applications throughout this decade.

Material Mix	Forecast for 1995		Forecast for 2000		
	Delphi IV	Delphi V	Delphi IV	Delphi V	Delphi VI
Integral body/frame					
Steel	80%	90%	90%	85%	84%
Aluminum	10	5	5	7	8
Composites	10	5	5	8	8
Space frame					
Steel	70%	87%	89%	75%	80%
Aluminum	15	5	6	10	10
Composites	15	8	5	15	10

STRATEGIC CONSIDERATIONS

Steel will remain as the overwhelmingly dominant structural material in both the integral body/frame and space frame designs through the year 2000. However, the use of aluminum and polymer-based composites is expected to expand, but rather gradually. Generally, the views in the present Delphi are consistent with those of Delphi V with slightly decreased expectations for composite materials in space frames. In any event, the magnitude of the forecast for aluminum and composites, while small, is very aggressive when compared with today's production levels, which are essentially zero. If even several percentage points of application are achieved, this would indeed be viewed as revolutionary, requiring very careful watching. This is a highly volatile area where major advances with alternate materials are possible and, indeed, likely. Also, considerable improvements in the application of more traditional, steel-based materials can be expected. This is an important area for many in the industry and must be monitored closely. In our opinion, the chances for surprises are rather high.

TECH-23. Consider these automotive exterior components. For each component, indicate the percentage of North American production that will be steel or all forms of plastic.

Automotive Components	Median Response					
	1995			2000		
	Steel	Plastic	Aluminum	Steel	Plastic	Aluminum
Hood (exterior)	88%	10%	2%	78%	15%	7%
Roof	94	5	1	90	8	2
Doors	94	5	1	85	10	5
Rear deck	88	10	2	80	15	5
Front fenders	89	10	1	80	15	5
Rear quarter panels	94	5	1	85	10	5
Automotive Components	**Interquartile Range**					
	1995			2000		
	Steel	Plastic	Aluminum	Steel	Plastic	Aluminum
Hood (exterior)	85/90%	10/10%	1/5%	75/85%	10/20%	5/10%
Roof	94/94	5/5	0/2	85/94	5/10	0/5
Doors	90/95	5/10	0/3	80/90	8/15	1/5
Rear deck	85/90	8/10	0/5	75/85	10/20	5/10
Front fenders	85/90	10/15	0/2	75/85	10/20	1/5
Rear quarter panels	90/95	5/10	0/3	80/90	7/15	1/5

SELECTED EDITED COMMENTS

- Aluminum is not ready for exterior surfaces in these applications.
- Doors will probably use steel structures with plastic skin.
- For ease of opening (weight) and dent resistance, plastic use will expand. Plastic use will depend on the success of Saturn, for example, and the longer-term acceptance of GM's APVs.
- Hoods and trunk lids will tend towards plastics for weight savings. Aluminum will not make it because of cost.
- Plastic horizontal panels will have a slower growth rate due to surface problems with recycling.
- I think aluminum, not steel or plastic, will gain in horizontal and structural panels that do not show.
- Note the use of plastic fenders and doors in the Saturn. We need to consider the impact of niche vehicles and local customization.
- Plastic skin with steel reinforcement is the way to go.
- The use of plastic panels is progressing more rapidly than imagined, reducing cost and weight and providing better corrosion resistance. Appearance and paint may be limiting factors. When will plastics replace glass? Scratch resistant coatings are already available.
- Weight reductions of 10-20% for all vehicles will be necessary by 2000, without reducing the interior package.

MANUFACTURER/SUPPLIER COMPARISON

While the two groups are in general agreement on the use of steel and plastic in exterior components, there is a difference of opinion regarding the use of aluminum. The differences are illustrated in the following table.

Automotive Components	Aluminum Exterior Components (percent of NAPPVs)			
	1995		2000	
	OEM	Supplier	OEM	Supplier
Hood	3%	5%	10%	7%
Roof	1	0	5	2
Doors	*	*	5	2
Rear deck	*	*	5	8
Front fenders	1	0	5	3

* no difference

COMPARISON OF FORECAST: MAT-23

The Technology and Materials panelists are in remarkably close agreement regarding materials applications for automotive exterior components. Their representative forecasts are within 1-2% of each other.

TREND FROM PREVIOUS DELPHI SURVEYS

This is the first Delphi to include aluminum as a material for automotive exterior components. The following tables illustrate the trend in material usage from Delphi IV through Delphi VI. From Delphi IV to Delphi V there was a significant increase in the forecasts for percentage of steel usage at the expense of plastics. The present Delphi does not show any major distortion of this trend. The very minor erosion in the use of steel indicated in the Delphi VI 1995 forecasts can be attributed to the penetration of aluminum. The increasing use of aluminum indicated in the Delphi VI year 2000 forecasts also appears to be responsible for the diminished use of steel.

Automotive Components	Forecast for 1995 Percent of NAPPVs					
	Steel			Plastics		
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1987 Delphi IV	1989 Delphi V	1991 Delphi VI
Hood	70%	90%	88%	30%	10%	10%
Roof	85	95	94	15	5	5
Doors	75	95	94	25	5	5
Rear deck	60	90	88	40	10	10
Front fenders	67	90	89	33	10	10
Rear quarter panels	70	95	94	30	5	5

Automotive Components	Forecast for 2000 Percent of NAPPVs			
	Steel		Plastics	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Hood	85%	78%	15%	15%
Roof	95	90	5	8
Doors	90	85	10	10
Rear deck	85	80	15	15
Front fenders	80	80	20	15
Rear quarter panels	90	85	10	10

STRATEGIC CONSIDERATIONS

This question is a repeat from both Delphi IV and Delphi V. The results of Delphi VI are generally consistent with those of Delphi V and suggest expectations for plastic body exterior panels have stabilized. However, as noted in the table, expectations are considerably below the role for plastics envisioned in Delphi IV (1987). The new stability is a suggestion of some maturation in the role of steel and plastics. The representative components selected were from two basic types: 1)

highly integrated components such as the roof and 2) those that are more easily separated or disagregated from the surrounding components, such as the door exterior, rear deck, or hood. As expected, highly integrated components are more likely to remain in conventional steel, whereas those that are less tied structurally to the surrounding elements exhibit greater potential for plastic-based materials. Steel is expected to remain the dominant material through the foreseeable future. The percentages forecast for plastics are indeed significant and represent a rather dramatic change in the industry. As we noted earlier, the industry has made considerable progress with steel at the automotive manufacturers and steel and stamping suppliers as well as with joint efforts, such as the Auto/Steel Partnership (an effort between the Big Three and the North American steel companies). The target for all new materials has indeed been moving swiftly. Generally, we sense there is a high degree of realism in terms of what it takes to process steel at world-class levels and an awareness of the major challenges with introducing new materials to traditional steel applications.

The possible role for aluminum in exterior components is a new issue raised in this Delphi. This will be explored in the follow-up question. It should also be noted that there appear to be rather significant differences in enthusiasm and capability within the industry with regard to plastics. The degree of uncertainty is evident by the relatively broad interquartile range of the year 2000 forecast. Obviously, developments must be watched closely because of the potential impact on a broad cross section of the industry.

A point that we raised in Delphi V with regard to this issue is worth repeating. There is a possibility that the customer could begin to specify materials because of perceived advantages. At the present time, the consumer does not appear to place particular value on any specific exterior material, although this may change particularly with the introduction of the aggressively priced Saturn, which features thermoplastic doors and fenders. If the customer perceives an advantage of a ding-free door or other benefits, the situation could shift rather dramatically and, obviously, skew the material picture over a relatively few years. If the customer places a premium value on plastic exterior components, the steel/plastic competition could be very interesting, indeed, even with the per-pound price advantage of steel.

It is important that all comparisons for materials be made at a world-class level of capability. It really does not make much sense to try to solve a deficiency in steel fabrication by switching to plastics. This appears to be far less likely than a few years ago because of a significant maturation of our understanding of competitive materials and a far better benchmarking capability within the industry.

With important recent efforts (e.g., Honda with its NSX, and considerable development activity at most of the automotive manufacturers and aluminum suppliers), aluminum must be considered a candidate for exterior applications. Other factors in this renewed interest may be related to recycling issues and to concern with possible new CAFE requirements, which could require substantial increases in fuel economy. Furthermore, there seems to be growing confidence in the use of non-traditional materials, as the technology has progressed rather substantially in the last few years. Economics, obviously, are key in terms of the value of a pound of weight saved and the tradeoffs with vehicle size and weight reduction. Still, as is evident from the data, plastics are expected to be at least two to three times as significant a factor as aluminum. The quartile ranges are very broad for plastics and aluminum, indicating a high level of uncertainty. As we noted in the prior question, developments must be watched closely because the chances for surprise are large. With continued high levels of investment in new technology by manufacturers and suppliers all over the world, change, indeed, will accelerate.

An additional perspective on these materials, particularly aluminum, is gained by considering the impact of relatively high-volume usage on the supply and demand issues (price and availability), and the basic economics of materials decisions. Even a relatively small increase in percentage of automotive application could have a significant impact on price volatility; if capacity is pushed by automotive demand, the economics could change rather markedly.

TECH-24. **The recyclability of automotive materials and related environmental concerns are significant issues confronting the auto industry, including OEMs and suppliers. Please rank on a scale of 1 to 5 (where 1 = extremely important, 5 = not important), the significance of the following potential barriers to the selection and/or utilization of each of the materials categories.**

Potential Barriers	Plastics/Polymers			Non-Ferrous metals			Ferrous Metals
	Unreinforced Thermoplastics	Reinforced Thermoplastics	Thermosets	Aluminum	Copper	Zinc	
Limited reapplication potential of recovered material	2.7	2.3	1.9	3.6	3.7	3.4	3.8
Recycling infrastructure	2.0	1.8	1.7	3.3	3.3	2.9	3.4
Energy required to process raw material	3.0	3.0	3.0	2.5	3.2	3.2	3.3
Energy required for recovery	3.0	2.7	2.7	3.3	3.3	3.0	3.2
Economics of reclamation/recycling process	2.2	1.9	1.7	2.9	2.9	2.6	2.9
Scrap value	2.4	2.3	2.3	3.0	2.9	2.8	2.7
Labeling/identification	2.1	2.2	2.2	3.7	3.9	3.7	2.9
Dismantling/disassembly	2.4	2.4	2.4	2.8	2.9	2.7	3.1
Ease of materials separation	2.1	2.0	2.0	2.8	2.9	2.9	3.3
Lack of design for disassembly	2.7	2.7	2.7	3.2	3.2	3.0	3.3
Industrial environment/health issues	2.5	2.4	2.4	3.4	3.4	2.9	3.4
Alloy content/contamination	2.8	2.9	2.9	2.7	2.9	2.8	2.8
Environmentally safe disposal	2.5	2.4	2.5	3.6	3.5	3.2	3.6

REPRESENTATIVE RESPONSES

- Avoid inseparable combinations that contaminate recycled base metal.
- There remain concerns over alloying elements which become impurities.

Ferrous Metals

- The use of energy to produce the raw material will be the primary concern.
- Dismantlers will be able to separate through color codes for easy identification and recycling.
- Foundry products will be increasingly difficult to dump/recycle.

Plastics/polymers

- Current scrap dealers can handle ferrous and non ferrous materials (with the exception of cadmium, lead, mercury, and other toxic materials). The waste/leftovers from the shredding process in the auto junkyard will become more of a problem as the non metallic, unrecyclable content of cars increases.
- Need for markets for post consumer products and new technology for processing.
- Tire recycling requires transportation to gather the items in a high-volume central, location efficiently. Asphalt additive components makes sense for tires, in addition to energy value.

MANUFACTURER SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

COMPARISON OF FORECAST: MAT-13

In a comparison of the responses of Technology and Materials panelists, there appears to be overall general agreement on issues related to automotive materials and environmental concerns.

However, there are some significant differences of opinion, primarily among these differences is the greater importance the Material panelists place on the environmentally safe disposal of plastics/polymers and zinc. The Materials panelists also express a greater concern for the reapplication of both ferrous and non ferrous metals than the Technology panelists.

Another significant difference of opinion is the concern on the part of the Materials panelists with regard to the recycling infrastructure for reinforced thermoplastics. The Technology panelists express a significantly greater concern for the labeling and identification of ferrous metals, their alloy content and contamination, and scrap value.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

The various issues of recycling have escalated dramatically in importance in the eyes of our panelists. We saw evidence of this in the previous forecast Delphi V, and this interest is amplified considerably in the present forecast. It should be noted that while major interest has been directed at various polymers and recyclability, most of the common automotive materials are coming under increasing scrutiny. Concerns range from steel components containing alloys like cadmium to high alloy aluminum castings. Also, from the responses we infer that an appropriate recycling approach goes well beyond focusing on the narrow issue of recyclability of individual materials, but rather prompt us to consider this from a total systems perspective, essentially total, life-cycle management. This suggests the product should be life-cycle managed from concept through design then out of the front door of the factory and ultimately into the back door to begin the cycle again. It is evident that this issue will have an increasing influence on both the design and production processes as well as the formulation of individual materials for use in vehicles. Design for recyclability is an issue of the 1990s that will create considerable stress for the automotive manufacturers and their suppliers. However, it will undoubtedly create a number of business opportunities for those who fully understand the impact on future vehicles.

Based on the number of major environmental issues in society including concerns with toxic materials and landfills, it would seem appropriate that industry should move aggressively to take a leadership position on various life-cycle issues. By doing so, they will ultimately have an opportunity to participate in the rule making that will surely follow. We view this as a matter of urgency for the industry to address and urge the formulation of appropriate strategies.

TECH-25. Do you expect either federal or state level government regulatory activity to enforce the recyclability of automotive materials within the coming decade?

Yes: 80%	No: 20%
Regulatory Issues	**Percent of panelists' responding positively**
Legislative activity on either federal or state level *	46%
Require that a percentage of Gross Vehicle Weight (GVW) be recyclable. This would include financial penalties and or incentives based on weight of non-recyclable materials.	41
Design/manufacturing constraints, e.g., ban or restriction on nonrecyclable materials	30
Establishment of uniform identification standards for materials to facilitate separation	13
Specific legislation regarding recyclability of plastics	13
Regulation or licensing of dismantlers and salvage yards	9
Specific legislation for disposal of used tires	9
Recyclability as a marketing/competitive factor	7
Expect no regulatory activity	6
Other Several responses dealt with the need for regulatory action regarding the safe disposal and recycling of fluids (battery acid and oil), freon, and lead.	

*Within this group, 22% of the panelists forecast that the initiation of legislation will occur first on a local or state level. The responses indicate a strong opinion that the prospective federal legislation will be predicated on the German model. There is also considerable concern that "legislation" will not be synonymous with "enforcement."

REPRESENTATIVE RESPONSES

- I expect regulatory activity after 2000 if the European effort (i.e., Mercedes-Benz) is successful.
- Individual states will come first followed by a federal law.
- Recycling deposits may be required with each new and used car purchase (title transfer) to fund research and provide incentive for recycling through refunds.
- Some constraints will occur on what materials are allowed to be used, especially in combination with others within a part or assembly.
- Tires, battery acid, lead, used engine oil, air pollution, water pollution, waste management, and in-plant environment will receive attention.

MANUFACTURER/SUPPLIER COMPARISON

There is no significant difference between the two groups of panelists regarding their expectations for some type of federal or state regulatory activity related to automotive materials. Eighty-two percent of manufacturer respondents and 78% of supplier respondents expect some form of regulation.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

This question compliments the previous one. Its responses show that panelists expect rather significant regulatory activity, which is consistent with growing concern for recycling as an automotive issue. The thoughts suggested have been generally categorized. A substantial proportion of the panelists expect some type of legislative action during the 1990s. Specific areas for policy initiatives include requirements that a significant percentage of the vehicle be made from recyclable materials, the introduction of manufacturing and design constraints, and the addition of material identification techniques.

The strong and broadly based responses from our engineering leaders suggest that the automotive industry should promptly begin to prepare a response to possible legislative thrusts, and, as noted in the prior question's strategic considerations, should assume a proactive leadership position to earn the right to join in the process of writing future rules. This clearly represents an area of threat to many within the industry, but for others it offers considerable opportunities. It must be a prominent factor in the strategic planning of auto manufacturers and their suppliers.

One very positive aspect of this entire issue for the industry is the potential buy-back of older vehicles. This could have a positive effect on fleet energy consumption, safety, and exhaust emissions. By helping manage the elimination of older vehicles from the fleet, a rather significant surge in the demand for newer vehicles could result; the used car market could, in effect, support the new car market as the impact is propagated through the various tiers of the used car market. Clearly, eliminating these older vehicles may be the most cost-effective way to achieve the kinds of improvements in air quality and energy consumption that the introduction of new, clean and efficient vehicles would bring.

TECH-26. **Regarding the issue of federal or state level regulatory activity to enforce the recyclability of automotive materials, please indicate your forecast regarding the probability of the following regulatory areas (where 1 = extreme probability, 3 = moderate, and 5 = no probability).**

Regulatory Activity	Ranking
Disposal of automotive fluids (e.g., battery acid, coolants, etc.)	1.7
Disposal of used tires	2.2
Mandate uniform identification standards to facilitate separation	2.3
Regulation/licensing of dismantlers/salvage yards	2.4
Recyclability of plastics/polymers	2.5
Financial penalties/incentives based on percentage of Gross Vehicle Weight (GVW) considered nonrecyclable	3.4
Require OEMs to take back and recycle/dispose of vehicle at end of product life cycle (per German proposals)	3.5

SELECTED EDITED COMMENTS

- The Orient and Europe are extremely concerned regarding this area. World environmental concerns will dictate strong legislation.
- As a result of regulations and as costs continue to rise, these issues will get to be a greater concern.
- Business opportunity will develop to make recyclability a profitable venture within the framework of the American entrepreneurial spirit, but it will take time.
- California may characteristically be the first state to follow Germany. These are very appropriate questions! Incentives such as refundable return-deposits on do-it-yourself sales of oils and oil filters are likely. CFCs may be supplied only in containers that can be applied to closed-loop recharging equipment. For all of these efforts to be globally effective, U.S. and European standards must be forced into use in developing countries.
- Major responsibility will be heaped on salvage yards. OEMs will escape.
- Manufacturers need to start setting up recycling facilities. They fully understand the task they have ahead.
- Recyclability is a significant need for society and, like clean air laws, regulatory activity will follow if the industry is not proactive enough.
- Possible financial penalties will be paid only by the manufacturer. The government would not put a "visible" tax on the vehicles paid directly by the consumer.
- This is really only part of the much larger question of recycling and disposal of all waste materials. Automobiles will probably not get separate or unique treatment.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

COMPARISON OF FORECAST: MAT-14

The Technology and Materials panelists are in close accord with respect to their prioritization of issues related to federal or state regulatory activity. Both panels give a high priority to the possibility of regulations, requiring the OEMs to reclaim and recycle or dispose of a vehicle at the end of the product life cycle. Financial penalties and/or incentives would be based on the percent of gross vehicle weight considered non reclaimable or non recyclable.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

In this question, which is a further extrapolation of the recycling issue, specific initiatives are suggested and the panelists respond regarding the probability of their occurrence. Some issues are ranked with high probability of occurrence such as controlled disposal of automotive fluids, better handling of tires, uniform parts identification procedures, licensing of dismantlers, and consideration of polymer recycling issues. This is further evidence that the technical leadership in the industry anticipates a significant level of activity with regard to life-cycle issues and reinforces our view that both manufacturers and suppliers should address these concerns promptly.

V. BODY AND CHASSIS PRODUCT TRENDS

TECH-27. What percentage of NAPPVs will use an integral frame or other designs in model years 1995 and 2000?

Design	Median Response			Interquartile Range	
	Est. 1990*	1995	2000	1995	2000
Integral body/frame or unibody	92%	92%	92%	90/93%	89/95%
Separate body/frame	7.3	6	4	5/7	2/6
Space frame	<0.7	2	4	1/3	2/9
TOTAL	100%	100%	100%		

* Compiled from: Automotive News Market Data Book, 1990.

SELECTED EDITED COMMENTS

- Carbon fiber "tubs" may emerge as an alternate design in limited production by 2000.
- Costs will determine change from current practice.
- Space frame is unlikely for any or few high-volume vehicle structures.
- Space frames will become more realistic as smaller engines and vehicles become necessary for fuel economy.

MANUFACTURER/SUPPLIER COMPARISON

There are no significant differences in the median forecasts of the OEM and supplier panelists. However, the upper quartile ranges of the supplier panelists' forecasts for space frame demonstrate a difference in expectations. The upper quartile range supplier forecast for 1995 is 5% and 10% for the year 2000, whereas the OEM panelists forecast 2% and 7%, respectively.

COMPARISON OF FORECAST: MAT-6

The Technology and Materials panelists are in close agreement regarding forecasts for unibody, separate body/frame, and space frame for the year 1995. For the year 2000, the Materials panelists forecast two-and-a-half times the percentage of space frames than do the Technology panelists (Materials = 10%, Technology = 4%). There is a corresponding decrease in the percentage of separate body/frame forecast by the Materials panelists for the year 2000 (85%) compared with the Technology panel projection for the same year (92%).

TREND FROM PREVIOUS DELPHI SURVEYS

In Delphi IV it was forecast that 90% of NAPPVs would possess an integral body/frame by 1995 and 7% would be of space frame design. In Delphi V the percentage of space frame vehicles dropped to 2% for 1995. Delphi V forecasts of 2% for space frame and 6% for separate body/frame in 1995 and 4% for both space frame and separate body/frame by the year 2000 are consistent with current Delphi VI forecasts.

STRATEGIC CONSIDERATIONS

The unibody frame design continues to be viewed as the dominant vehicle structure through the year 2000. In fact, we find significant consistency in the forecast between Delphi VI and Delphi V. The forecasts are almost exactly the same.

The space frame appears to be growing in importance at the expense of the separate body frame design. As we observed in our analysis in Delphi V, there are possible changes in basic construction techniques on the mid- and long-term horizon that could rather dramatically alter the forecast. While this would not be likely during the next few years, near the end of the decade the likelihood of fundamental change in this area increases. It should also be noted that there are wide

differences of opinion within the industry with regard to relatively new systems such as the space frame. Some manufacturers are rapidly developing second- and third-generation, space-frame capabilities whereas others have only modest experience.

As interest in new body-exterior and structural materials accelerates, and demands for improved fuel economy through weight, but not necessarily size, reduction occur, some very creative and innovative concepts may emerge. At the same time, the traditional techniques are being refined rather significantly. This has certainly been observed in the efforts of the Auto/Steel Partnership.

What is conventional today was far from conventional five and ten years ago because of the dramatic improvements that have been made in most elements of the body-design and fabrication process. Despite the stability of this forecast, we would reiterate that this basic technology must be watched closely in the years ahead. Breakthroughs in materials, design, and construction techniques could have a profound impact on the basic structure of the vehicle.

TECH-28. What percentage of North American-produced passenger cars will incorporate the following suspension features in the years 1995 and 2000?

Suspension Features	Median Response		Interquartile Range	
	1995	2000	1995	2000
Front Suspension Configuration				
MacPherson struts	80%	80%	75/80%	70/90%
Twin A-Arm	20	20	10/20	10/25
Rear Suspension Configuration				
Independent	60%	75%	30/80%	40/90%
Non-Independent	40	25	20/70	10/60
Springs				
Air	3%	5%	1/7%	2/10%
Oil/fluid	2	5	1/4	3/5
Composites	5	10	2/8	5/15
Steel	90	80	83/95	68/90

SELECTED EDITED COMMENTS

- "Cab-forward" styling will influence suspension.
- Composite leaf springs will not continue to penetrate because of functional inferiority.
- It seems most front-wheel drive (FWD) vehicles have independent rear suspensions. Also, some more technologically advanced rear-wheel drive vehicles (RWD) have independent rear suspensions.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in agreement regarding their forecasts for front suspension configurations. There is some difference in their projections for rear suspension configurations: the OEMs forecast a 60/40 percent split in 1995 for independent and nonindependent, respectively, and the suppliers forecast a 75/25 percent split. The only significant difference between the two groups, with regard to springs, is in the composite springs percentage penetration in the year 2000: OEMs project 10%, and suppliers project 6%.

TREND FROM PREVIOUS DELPHI SURVEYS

Forecasts for suspension features from Delphi V to Delphi VI indicate a slight increase for struts by the year 2000 and a significant increase for independent rear suspension for both 1995 and 2000. While there are some observable increases and decreases in forecasts for the various types of springs, they do not appear to be significant. The following table illustrates these trends.

Suspension Features	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Front Suspension				
MacPherson Struts	80%	80%	75%	80%
Twin A-Arm	20	20	25	20
Rear Suspension				
Independent	50%	60%	60%	75%
Nonindependent	50	40	40	25
Springs				
Steel	88%	90%	82%	80%
Air	5	3	5	5
Oil/fluid	2	2	3	5
Composites	5	5	10	10

STRATEGIC CONSIDERATIONS

In general, it appears that the basic suspension features of North American-produced cars will remain reasonably stable through the coming decade. In the front suspension, McPherson struts are expected to dominate although there will be a significant role for various twin A-arm designs. With the twin A-arm, a broad quartile range suggests a reasonable level of uncertainty which might be interpreted to mean that different companies have significantly different strategies regarding the use of this design. In rear suspensions, continued steady growth is forecast for independent designs as they replace nonindependent or solid axle configurations. On the other hand, here too, we see a broad interquartile range, which is consistent with uncertainty and/or (as noted above) significantly different future plans by the various manufacturers.

Finally, we address suspension springs. Panelists expect the basic steel spring to prevail through the 1990s, although a growing role for other types including composites, fluid, and air suspensions is anticipated. Composite springs have generally stronger support than the other alternative designs. The interquartile range is reasonably broad, suggesting the comments made above with regard to suspensions are appropriate for springs.

We believe it is prudent to recognize that suspensions may be an area of the vehicle in which we could see significant innovation and perhaps entirely new concepts emerge in the next few years. Considering the way we have asked the question, it appears that a more evolutionary process is underway, but we always should be mindful that a new technology could emerge, which could dramatically alter suspensions, although probably not before 1995. Thus, while we anticipate stability, we must be constantly alert for surprises.

TECH-29. What percentage of North American-produced passenger cars will have the following chassis/suspension features in 1995 and 2000?

Passenger Cars: Chassis/Suspension Features	Median Response		Interquartile Range	
	1995	2000	1995	2000
Steering				
Electrical/electronic power steering	5%	10%	1/5%	5/15%
Active four-wheel steering	1	3	1/3	1/5
Ride/Handling				
Passive control (present system)	88%	78%	79/94%	60/88%
Passive driver-selected	5	10	3/10	5/15
Semi-active (damping control)	5	8	2/9	4/12
Active (spring and damping control)	2	4	1/4	2/10

SELECTED EDITED COMMENTS

- As electronic components decrease in price, electric power assist will become comparable in cost to current hydraulic systems.
- Safety demands will warrant application in more vehicles.
- Electronically assisted steering and brakes are two items that will require a "leap of faith." They are technically feasible, but people will still be comforted with a hard, mechanical link.
- The weight and cost penalties and power consumption of active suspension systems will hinder their widespread applications and will be found only in high-end luxury vehicles.
- Total energy efficiency will provide the major push. Wider revolutions-per-minute range of new engines will be a disadvantage for conventional power steering systems. This includes electronic variable assist for traditional hydraulic systems.
- Vehicle front weight must be reduced to allow use of electrically-powered steering.

MANUFACTURER/SUPPLIER COMPARISON

As illustrated in the following table, the manufacturer and supplier panelists demonstrate a reasonably good consensus regarding the application of electric power steering and four-wheel steering in passenger cars.

Chassis/Suspension Features	Passenger Cars			
	Forecast for 1995		Forecast for 2000	
	OEM	Supplier	OEM	Supplier
Electric power steering	3%	5%	10%	10%
Active four-wheel steering	1	2	2	4

COMPARISON OF FORECAST: MKT-33a

With regard to the technologies surveyed, the Marketing panelists were asked to forecast the penetration rates of the designated features for the total U.S. market, including imports and domestics. The Technology panelists were asked to present their forecasts for North American-produced passenger vehicles (NAPPVs), including traditional American manufacturers (TAMs) and new American manufacturers (NAMs/transplants), excluding imports. Given these conditional stipulations, the Technology and Marketing panelists' forecasts for four-wheel steering are surprisingly similar. The Technology panelists' forecast for NAPP cars is 1% for 1995 and 3% for 2000. The Marketing panelists' forecast for total U.S. domestic market penetration rate is 2% for 1995 and 3% for the year 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

As evidenced in the following table, there has been a progressive erosion in the forecasts for both electrical/electronic power steering and active four-wheel steering. Projections for electronic power steering have experienced a 50% reduction in percentage of application since the 1989 Delphi V study. Active four-wheel steering forecasts demonstrate an even greater reduction in penetration rates from Delphi V to Delphi VI.

Chassis/Suspension Features	Passenger Car				
	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Electrical/electronic power steering	25%*	10%	5%	20%	10%
Active four-wheel steering	5	5	1	8	3

*The Delphi IV forecasts for electronic power steering and four-wheel steering includes cars, vans, and light trucks. Subsequent Delphi forecasts are only for passenger cars.

STRATEGIC CONSIDERATIONS

Advanced electronic steering and suspension systems will penetrate future North American-produced passenger cars. However, Delphi VI panelists view electrical/electronic power steering systems usage with less optimism than previous Delphi panels. Interquartile ranges for both 1995 and 2000 are wide (indicating a great deal of uncertainty) and the upper range of the current survey is below the median response of past panelists. Perhaps this is an indication that issues of cost (compared to current hydraulic systems), safety, reliability, and durability have not been addressed as rapidly as expected. The panelist's comment regarding a "leap of faith" is an important perception and consideration. Field experience is essential for expanding the comfort zone of new technology. Electric vehicles using these systems will provide this field experience. However, electric vehicles will not be produced in significant numbers until the 1998-2000 time horizon. Therefore, suppliers and manufacturers need to use the next six years to develop new hardware, testing procedures, regulatory and certification rules, public education programs, and field test experiments.

Suspension systems will also be effected by an increase in electronic content. Advanced systems may comprise 22% of the 2000 market. Cost, weight, durability, safety, and consumer perception are issues manufacturers and suppliers need to address before widespread applications will occur. Just as with advanced steering systems, total customer value must be increased to justify the use of these systems. An expanded systems analysis approach is required to assure the complete vehicle maximizes customer value by optimizing all component subsystems across cost, weight, and performance budgets and objectives.

TECH-30. What percentage of North American-produced light trucks and vans will have the following chassis/suspension features in the years listed?

Chassis/Suspension Features	Light Trucks/Vans			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Steering				
Electrical/Electronic power steering	1%	4%	0/2%	2/8%
Active four-wheel steering	0	1	0/1	0/5
Ride/Handling				
Passive control (present system)	95%	90%	90/99%	80/95%
Passive driver-selected	4	5	1/5	2/10
Semi-active (damping control)	2	4	0.6/5	2/10
Active (spring and damping control)	0	1	0/1	0/4

SELECTED EDITED COMMENTS

- Expense will prohibit these technologies.
- There is not much interest in other suspension systems.
- Advanced ride and handling controls are particularly strong in selected special vehicles.
- The Japanese will offer these first as a spin-off from their wide use on passenger cars.
- The weight and cost penalties and power consumption of active suspension systems will hinder their widespread applications and will be found only in high-end luxury vehicles.
- Trucks need dual control systems for dual usage.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists demonstrate a good consensus for electric power steering and four-wheel steering in light trucks and vans. For 1995, both groups forecast 1%; for the year 2000, the OEM panelists forecast 3%, and suppliers 5%. For active four-wheel steering, both groups forecast 0% for 1995 and 1% for the year 2000.

TREND FROM PREVIOUS DELPHI SURVEYS:

As indicated in the following table, there has been a considerable lessening of expectations for light-truck application of electronic power steering.

Chassis/Suspension Features	Light Trucks				
	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Electrical/electronic power steering	25%*	5%	1%	10%	4%
Active four-wheel steering	5	0	0	2	1

*The Delphi IV forecast for electronic power steering and four-wheel steering includes cars, vans, and light trucks. Subsequent Delphi forecasts are only for light trucks and vans.

STRATEGIC CONSIDERATIONS

This was a very interesting question, particularly when we consider how dramatically opinion has shifted within the industry with respect to electric/electronic power steering. As recently as 1987, panelists forecast a reasonably significant role for electric/electronic power steering in light trucks and vans. In the present forecast, expectations for electric/electronic power steering and active four-wheel steering are very modest for application to light trucks and vans, and much less than for passenger cars. The same general trend is observed with respect to ride and handling features, including various types of driver selected controls, semi-active, and active systems. As many of the differences between light trucks, vans, and passenger cars diminish in terms of feature content, it is surprising that these forecasts are as low as indicated. On the other hand, it may reflect the realities of a market that is going to be increasingly cost and value conscious.

As in most other areas of emerging technology, it is highly desirable to track trends carefully and to note how various technologies transfer from passenger cars to the light truck and van segment.

It should be observed that most of the features discussed in this question, and their roles in future vehicles are highly dependent on developments yet to come. A breakthrough that would substantially reduce cost and enhance function could dramatically escalate expectations for any of these technologies in future light trucks and vans.

TECH-31.* **Of the percentage of electrical/electronic power steering units in NAPPVs, what percentage will consist of electronic manipulation of steering and what percentage will be hydraulic with electronic variable assist?**

Power Steering	NAPPVs			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Electric power/electronic control	8%	15%	1/25%	5/50%
Hydraulic with electronic control	40	35	5/80	10/60

SELECTED EDITED COMMENTS

- Electric motor assist has not been positively evaluated. It may be used on electric-powered vehicles.
- Hydraulic with electronic control (high speed cutout) is already here. Electric vehicles will be exclusively electronic.
- True electric-motor/gearing power steering will generally be found only on sub-1.5 liter cars, as in Japan.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

As noted earlier, expectations for electric/electronic powertrain steering have diminished. With this question we further explore electrical/electronic power steering and the emerging concept of adding electronic control to traditional hydraulic actuation. We observe considerable enthusiasm for this technology in Delphi VI, but with some decrease in expectations for the latter part of the decade. The interquartile range in all of these forecasts is broad, indicating a high level of uncertainty and possible different strategies by the various manufacturers. Since this question was initially posed in the second round of the Delphi process, we did not have time to refine it to a higher level of consensus. Consequently, the median response could shift rather significantly in an additional round of the Delphi process. With an interquartile range as broad as it is in this question, both automotive and component manufacturers should be alert to the possibility of significant changes in thinking over a relatively short period of time. The response to this question should be considered seriously, but with a great deal of caution.

*Note: This question was not written properly and consequently the results should only be used in a qualitative manner. However, since this information is related to important industry issues we have included the data. The question should have been stated as: Of the NAPPVs with power steering, what percentage will have electric power steering with electronic control, and what percent will have hydraulic with electronic control. The remaining percentage, by default, will be NAPPVs with traditional hydraulic control.

TECH-32. What percentage of NAPPVs will use rear disc brakes in 1995 and 2000?

Rear Disc Brakes	Est. MY 1990	Median Response		Interquartile Range	
		1995	2000	1995	2000
Passenger cars	26%	30%	40%	30/35%	35/60%
Light trucks	0	3	5	0/5	3/15
Vans	0	5	10	0/10	5/20

SELECTED EDITED COMMENTS

- It depends on the ability to increase rear emergency-brake effectiveness on high-front-weight vehicles through advanced brake controls.
- If CAFE forces performance reduction, there will be little need for rear discs.
- Increasing ABS penetration will result in more rear disc brakes.

MANUFACTURER/SUPPLIER COMPARISON

As shown in the following table, the forecasts of the OEM and supplier panelists present significantly different forecasts for NAPPVs. The supplier panelists indicate a 2- to 3-times higher penetration rate for rear disc brakes except for passenger cars in 1995.

Rear Disc Brakes	OEM		Supplier	
	1995	2000	1995	2000
Passenger cars	30%	40%	30%	50%
Light trucks	2	5	5	10
Vans	2	6	5	10

TREND FROM PREVIOUS DELPHI SURVEYS

Expected 1995 and 2000 rear disc applications have increased for passenger cars since 1989. Light truck expectations for 1995 are greater than they were in 1989 but significantly lower than 1987. The following table presents these trends.

Rear Disk Brakes	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Passenger cars	40%	10%	30%	20%	40%
Light trucks	15	1	3	5	5
Vans	20	2	5	5	10

STRATEGIC CONSIDERATIONS

This question has been asked in several Delphi studies because of the still rather modest application of rear disc brakes and continued speculation about the potential for rear disc brakes. We have observed some rather significant swings in prior Delphi forecasts and, again, this is evident with the present forecast. For example, in the Delphi IV forecast for 1995, 40% of passenger cars were expected to be equipped with rear disc brakes. By Delphi V, the forecast dropped to 10% and in Delphi VI, the forecast has been expanded to a 30% level. This apparent resurgence of interest, to some extent, is also evident for light trucks and vans, but the major application for rear disc brakes is expected to be passenger cars. The forecast suggests, particularly for passenger cars, rather significant shifts in technology that could have a profound impact on brake component suppliers. The growing use of ABS and remaining concerns with rear disc emergency brakes will be factors in the decision as well as cost, which still appears to favor rear drums. It must be noted that with a high fraction of front-drive vehicles, the brake performance requirement of the rear system is relatively modest compared with the front system because of the high, static, front weight and further, forward, dynamic weight shift during braking. The superior heat-management capabilities of disc brakes are obviously important for the front, but less so in the rear. The entire issue is not clear cut and uncertainty could remain for some time.

TECH-33. What percentage of North American-produced passenger cars will be equipped with anti-lock brakes and traction control in 1995 and 2000?

Brake and Traction Control Features	Est. 1990 MY*	Median Response		Interquartile Range	
		1995	2000	1995	2000
Anti-lock brakes	7.4%	25%	75%	25/40%	60/90%
Traction control (anti-spin)	0.1	5	15	3/5	10/25

* Source: Automotive News

SELECTED EDITED COMMENTS

- ABS will be a 100% marketing requirement by late 1990s. There is no or low need for traction control in many areas of the United States.
- ABS will be mandated, but will become almost standard due to customer demand and expectations. Traction control is the next logical step after ABS is implemented.
- Anti-lock would go to 100% in 2000 if legislated, which has a 50% chance of happening by then.
- Cost will prevent higher penetration of these features.
- FWD traction control will be seen as a real low-cost alternative to four-wheel drive.
- I expect Congress to require the use of ABS by 2000, therefore ABS will be 100%. Traction control will be limited to high-end vehicles.
- Legislation will require ABS by 2000. Traction control forecast includes viscous couplings and limited slip differentials.
- This assumes no legislation for ABS; however, legislation is likely by 2000 unless the auto industry takes a lead in marketing ABS. Many different levels of traction control will be available, with a wide variance in performance, but cost for moderate performance systems will be low on ABS-equipped vehicles.
- Traction control should be a natural "pull through" as ABS becomes widespread.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists do not differ in their forecasts for ABS and traction control by more than 5%. The supplier forecasts for ABS were higher than the OEMs forecast.

COMPARISON OF FORECAST: MKT-33b

The Marketing panelists were asked to separate their forecasts for ABS by passenger cars and light trucks, including domestics and imports. The Technology panelists were surveyed for total North American-produced passenger cars (TAMs and NAMs). The Marketing panelists forecast an ABS penetration rate for passenger cars of 25% for 1995 and 50% for the year 2000. The forecast of 50% for 2000 is, however, questionable. Considering competitive market factors and the very real possibility of ABS being legislatively mandated (see Comments), the forecast appears unrealistically low. The light truck forecasts appear to be more realistic at 80% for 1995 and 90% for the year 2000. At the same time, the Technology forecast of 75% for 2000 does not appear to present much of a competitive advantage.

There is also disagreement between the Technology and Marketing panelists regarding traction control. Even on average, the Marketing panelists are significantly lower in their forecasts for the percentage of application of this technology: passenger cars to be 2% for 1995 and 7% for the year 2000; light trucks are forecast at 2% for 1995 and 5% for 2000. This compares with the Technology NAPP car forecast of 5% for 1995 and 15% for 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

Although 1995 forecasts for the rate of application of anti-lock brake systems (ABS) and traction-control (anti-spin) systems have demonstrated a steady decline since 1987, the forecasts for the year 2000 appear to achieve stability.

Brake and Traction Control Features	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Anti-lock brakes	50%	30%	25%	70%	75%
Traction control	20	5	5	15	15

STRATEGIC CONSIDERATIONS

The forecast for both the anti-lock braking systems (ABS) and traction-control system (TCS) are reasonably consistent with those of Delphi V. Significant penetration is envisioned for ABS to the point where one could almost suggest that it will be standard by the turn of the century. Traction control is expected to expand on a percentage basis rather significantly but to nowhere near the level forecast for ABS. The quartile range is reasonably broad, suggesting there is still significant uncertainty. It should be noted that a number of the panelists have suggested that legislation is likely for the ABS.

Several key factors seem to be influencing the forecast. One obviously relates to the continuing cost reduction of ABS, which make it more affordable, and the other is the general increase in demand for safety features on the part of the consumer, which is obviously being enhanced by aggressive marketing on the part of manufacturers. We believe that ABS is an important safety feature that is increasingly being accepted by the public. It may be mandated by legislation by the end of the decade, and will, therefore, become a standard feature in modern vehicles. Several ABS developments in the last few years must be considered as near breakthroughs, particularly with regard to system cost.

It seems clear that traction control, while less popular at the moment, may expand rather rapidly. This is due, in part, to the fact that many of the same system elements (e.g., wheel speed sensors and other components) are required for ABS and may serve double duty for traction control. Traction control may provide the needed marginal surface, tractive capability to be considered a good tradeoff against the much higher cost and weight penalty of four-wheel drive. There is considerable effort on traction-control systems at the present time, and if the cost increment beyond ABS becomes nominal, its use could escalate rapidly.

Several manufacturers will probably attempt to use these features as important product differentiators. As many of the basic quality or value characteristics of vehicles become equalized across products, features such as ABS and traction control could take on a higher level of importance as product differentiators.

TECH-34. Do you expect government regulations to require Anti-lock Braking Systems (ABS) in passenger cars and/or light trucks?

ABS Regulatory Activity			Median Response	Interquartile Range
Passenger cars	Yes: 52%	No: 48%	2000	1997/2000
Light trucks	Yes: 52%	No: 48%	2000	1997/2000

SELECTED EDITED COMMENTS

- Cost will preclude dictation by government.
- Costs are down to produce outstanding safety features; ABS will be mandated as was the air bag.
- Depends on rate of increase in unregulated use of ABS.
- I expect market demand will bring forth systems that customers will perceive as good values.
- Manufacturers must move aggressively to make ABS available or standard on all cars over the next three to four years.
- No, because ABS will be almost standard anyway.
- Regulations will not be developed if the industry does a credible job of providing affordable ABS and actively marketing it. I think the marketplace and customer demand will control this issue.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in agreement.

TREND FROM PREVIOUS DELPHI SURVEYS

Compared to Delphi V panelists, Delphi VI panelists are less likely to expect passenger car and light truck legislative activity. Sixty-three percent of Delphi V panelists believed passenger car ABS regulation would occur by 1998. Sixty-one percent of Delphi V panelists believed light truck ABS regulation would occur by 2000. Regulatory action is expected by slightly more than 50% of the current panel. The rapid application of ABS systems, as standard and optional equipment, appears to be keeping the market ahead of the legislative activity.

STRATEGIC CONSIDERATIONS

The Technology panelists were almost evenly divided with regard to expectations for government-mandated ABS. Slightly more than half of the panelists expect ABS legislation for passengers cars and light trucks. These expectations are considerably reduced from those of Delphi V where more than 60% of the panelists expected government regulation. We believe it will be difficult for the governmental regulatory bodies to avoid regulation of this feature that is being led by the industry itself in application. Apparently, this is a volatile issue with highly divided opinion and events must be watched closely by stakeholders in this area of the vehicle. It further must be kept in mind that regulation is very difficult to predict with any degree of reliability in view of the complex political pressures that abound today. However, given the choice to regulate or not regulate, government generally pursues a regulatory initiative.

TECH-35. What percentage of North American-produced passenger cars will have standard spares, mini-spares, or no spares in the 1995 and 2000 model years?

NAPPV with:	Median Response		Interquartile Range	
	1995	2000	1995	2000
Mini-spare	93%	94%	90/95%	90/95%
Standard spare	7	3	5/10	2/5
No spare	0	3	0/0	0/5
TOTAL	100%	100%		

SELECTED EDITED COMMENTS

- One-hundred percent airless spare by 2000.
- A run-flat tire must come soon!
- Airless spare will dominate.
- Distribution is dependent upon availability of run-flat tires and public acceptance.
- "No spare" is probably unacceptable from customer view, even if technically feasible.
- No spare must imply a "run-flat" tire.
- Non-pneumatic spare tires are now fully approved by the U.S. government and programs are moving to implement.
- The non-pneumatic spare tire saves space and weight and will move faster if CAFE is stringent.
- Unless there is a radical change in tire technology, every car will need some kind of spare.
- I expect a breakthrough in the technology that would allow the elimination of spares.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in agreement on the distribution of percentages of spare-tire types.

TREND FROM PREVIOUS DELPHI SURVEYS

It is apparent that because of weight and packaging constraints, the mini-spare tire will continue to increase in usage at the expense of the standard spare tire. Although the popularity of the "no spare" has decreased since Delphi V, it is expected to realize market penetration of 3% by the year 2000. The following table presents these trends.

NAPPVs with:	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Mini-spares	80%	93%	80%	94%
Standard spares	15	7	10	3
No spares	5	0	10	3

STRATEGIC CONSIDERATIONS

The role of the spare tire in future passenger cars continues to be viewed as relatively uncertain. However, general trends are becoming more evident. For example, the expectations for use of the standard spare tire is considerably less than envisioned in Delphi V. In the present Delphi, only 3% of the year 2000 vehicles are expected to use the standard spares, whereas the forecast of Delphi V was for 10%. At the same time, there is considerably decreased enthusiasm for the elimination of the spare tire compared with prior forecasts. The mini spare dominates the forecast perhaps, in part, because of some exciting new technology being developed. Furthermore, there is considerably less uncertainty than observed in past Delphi surveys as evidenced by the narrowing of the quartile range. Thus, industry consensus seems to be developing along the median forecast.

There is no question that technological trends in tire development, as well as that of spare tires, must be watched closely because of the number of technological programs around the world. The incentives to eliminate the spare tire remain strong both with regard to weight and packaging, and, in fact, if we see a significant increase in CAFE requirements, this would put an additional premium on the weight and volume aspects of the spare tire. The implications for tire and associated hardware producers are significant, and trends must be watched closely. In an ideal world, it would be highly desirable to eliminate the spare, but it is also necessary to ensure the customer of a totally fail-safe and inconvenience-safe, failure mode of a tire. We probably will not achieve that level of capability in the foreseeable future.

TECH-36. What percentage of North American-produced passenger cars will incorporate the following tire features?

Tire Features	Median Response		Interquartile Range	
	1995	2000	1995	2000
Puncture resistant	5%	10%	3/5%	5/10%
Self-sealing	5	10	2/5	5/12
Run-flat	1	5	0/1	2/5
Failure-sensing devices	1	5	1/3	2/5

SELECTED EDITED COMMENTS

- Central tire inflation will also be used.
- Failure-sensing devices will be 95% in 2000. A simple additional algorithm of ABS.
- Failure-sensing devices are probable as a by-product of more prevalent use of ABS systems and a greater use of computers to determine low or flat tire conditions.
- Much of this technology could be applied at a reasonable cost, but tires have gotten so much more reliable and durable that these features may not be viewed as necessary.
- There is not much change on the horizon other than general robustness of tires.
- Puncture resistant and self-sealing categories should be combined as they overlap.
- Safety will sell in the 1990s so these will be market requirements.
- When cost of a non-pneumatic spare gets closer to the pneumatic spare, there will be a mass movement toward non-pneumatic.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in very close agreement on the percentage of NAPPVs that would incorporate these tire features.

TREND FROM PREVIOUS DELPHI SURVEYS

As illustrated in the following table, forecasts for the utilization of the tire features listed have experienced a dramatic reduction since the 1989 Delphi V.

Tire Features	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Puncture resistant	20%	5%	30%	10%
Self-sealing	10	5	12	10
Run-flat	5	1	10	5
Failure sensing	2	1	8	5

STRATEGIC CONSIDERATIONS

In this question, we explore a number of technologies related to automotive tires, including failure-sensing devices, puncture resistance, and run-flat and self-sealing designs. We find generally less optimism in Delphi VI on the future use of all technologies then we did in Delphi V two years ago. We note a reasonably significant decrease in the interquartile range, suggesting that industry consensus is stronger with regard to these tire features. A more conservative ethic appears to be emerging in the 1990s with customers as well as the manufacturers becoming more cost and value conscious. The cost of delivering the added value of these features may be higher than originally anticipated. The technology has advanced to the point where we have a better sense of what we can and cannot do, and the tighter interquartile range is perhaps related to this more realistic assessment of the technology. Modest growth from the present level is forecast in all of these tire technologies. Most will probably be used in more up-scale or leading-edge products that can justify the cost. In some areas, (e.g., low-pressure warning devices) we expect significant new technologies to appear. Our recent history suggest that it is very difficult to forecast new technology in electronics and, indeed, we are aware of some technologies that might offer low-pressure warning at a relatively low cost; this in turn could rather significantly change the forecast. Several comments related to the use of ABS electronics for failure sensing are very intriguing and appear reasonable. We think this warrants careful watching.

Also, we must keep in mind that all of these features have strong safety connotations, and the pressure to increase vehicle safety could cause any or all of these to accelerate because of consumer demand. Of course, with the possibility of tighter fuel-economy standards, any aspect of tire design increasing rolling resistance will not be attractive.

VI. VEHICLE INSTRUMENTATION/ENTERTAINMENT SYSTEMS

TECH-37. What percentage of NAPP cars will display warnings for the following vehicle monitoring systems in the years indicated?

Vehicle Monitoring Systems	Median Response		Interquartile Range	
	1995	2000	1995	2000
Scheduled maintenance				
Oil change	5%	25%	5/15%	15/50%
Unscheduled maintenance/failure detection				
Brakes	10%	20%	2/75%	5/100%
Brake fluid level	5	10	2/15	5/50
Engine coolant level	5	25	5/20	10/50
Engine timing problem	5	10	1/15	2/50
Transmission fluid level	3	10	1/5	5/20
Steering fluid level	3	5	0.1/5	2/20
Brake pad thickness	2	7	0/5	1/20
Tire pressure	2	5	1/2	3/10
Tire wear	0	0	0/1	0/2
Exhaust leak	0	0	0/1	0/3
Engine fire	0	0	0/1	0/2
Fuel leak	0	0	0/1	0/2

SELECTED EDITED COMMENTS

- Brakes--all ABS systems will be monitored.
- Display warnings will tend to be generic rather than specific.
- Exhaust leak monitoring is defined as after the catalytic convertor.
- Monitoring lights and reminders must be 100% accurate and reliable, otherwise the result will be customer dissatisfaction.
- New engine-control modules should detect engine timing/computer problems and may be able to detect exhaust levels upstream of catalyst.
- Warning displays must be easily reset to allow do-it-yourself maintenance. Brakes are already monitored in some way.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Significant growth on a percentage basis is expected in many areas of warning displays related to such maintenance issues as oil changes, fluid levels, and brake performance. A rather high level of uncertainty is suggested by the broad interquartile range on a number of these diagnostic items. As the manufacturers strive to deliver increased value to their customers, and as sensitivity to safety and inconvenience issues increases, it is clear that there is a trend to providing more information to the driver/operator. The various comments in this question suggest some interesting points, such as the ability to deal with do-it-yourself maintenance and a necessity to assure perfect accuracy and reliability. The features may represent an important value-added dimension of future vehicles. Engineers will be challenged to cleverly provide these functions with minimum additional cost and technology. These warning displays are a good fit with the expected growth of a more comprehensive, overall, vehicle-diagnostic strategy of the manufacturers. Because of the high rate of increase in implementation expected, this area of technology must be watched closely over the next few years.

TECH-38. What percentage of NAPPVs will utilize the following placement themes (positions) for the wiper/washer controls in the years indicated?

Wiper/Washer Placement Themes	Median Response			Interquartile Range		
	Current Est.	1995	2000	Current Est.	1995	2000
Stalk-mounted controls	54%	61%	59%	40/70%	42/70%	44/75%
Conventional instrument panel with conventional switches panel-mounted	34	21	19	20/40	10/30	5/30
Fingertip reach controls (pod/extension to put controls at fingertip)	12	16	19	5/20	6/23	10/28
Steering hub-mounted controls	0	2	3	0/2	0/5	0/5
Voice-operated controls	0	0	0	0/0	0/0	0/2
Touch-sensitive CRT	0	0	0	0/0	0/1	0/2

SELECTED EDITED COMMENTS

- There will be a redesign effort in fingertip reach controls.
- With the aging population, ergonomics and visibility will become more important.

MANUFACTURER/SUPPLIER COMPARISON

The following table indicates where differences exist between the OEM and Supplier forecasts for wiper/washer control placement themes.

Wiper/Washer Placement Themes	Percent NAPPVs			
	OEM		Supplier	
	1995	2000	1995	2000
Stalk-mounted controls	60%	60%	50%	50%
Steering-hub-mounted controls	0	0	3	5

TREND FROM PREVIOUS DELPHI SURVEYS

The current Delphi survey gave respondents a wider variety of location theme options. While Delphi V and Delphi VI are not exactly comparable, stalk-mounting and pod extensions are the clear trend at the expense of traditional instrument panel locations

STRATEGIC CONSIDERATIONS

The panelists indicate that although there is a trend to stalk-mounted controls at the expense of conventional panel-mounted switches, there is no significant movement towards more hi-tech, stylized wiper/washer placement themes. It is clear that stalk-mounted controls will continue to predominate well into the next decade. However, the very broad IQRs for stalk-mounted controls and the generally very broad IQRs for conventional placement themes indicate that there remains a considerable degree of uncertainty regarding the future placement of wiper/washer controls.

An increasing emphasis on ergonomics is compatible with the forecasts for fingertip reach controls. This may be reflective of a response to the aging driver. Again, the very broad IQRs represent a considerable degree of uncertainty regarding these placement themes.

TECH-39. What new vehicle instrumentation developments do you expect on North American-produced passenger cars within the next ten years?

Instrumentation Developments	Median Response		Interquartile Range	
	1995	2000	1995	2000
Display technology for speedo/tach/fuel cluster				
Electro-mechanical	50%	40%	40/65%	25/50%
Vacuum-fluorescent display (VFD)	15	20	10/20	15/25
Liquid-crystal display (LCD)	5	10	5/10	5/20
Light emitting diode (LED)	5	10	1/17	1/20
Speed display format				
Analog (pointer) display (includes electronic and simulations)	70%	75%	60/85%	50/85%
Digital	25	25	15/40	15/50

DISCUSSION

While there has been considerable promotion of electronic display technology within the last few years, it appears that a large fraction of this market will remain electro-mechanical well into the next century. This continuing dominance of conventional, electro-mechanical, analog technology may be due to a combination of the higher cost, the reliability of electronic displays, and the degree of comfort or facility that the consumer feels when reading a digital display.

SELECTED EDITED COMMENTS

- Electro-mechanical is a fad today and will die out. The analog electronic will increase and then lose favor in the out years.
- VFD will grow, as it is fairly low cost, not better.

MANUFACTURER/SUPPLIER COMPARISON

The following table indicates that there is a significant disparity between the forecasts of the OEM panelists and the supplier panelists regarding projections for vehicle instrumentation/display technology by the year 2000. A perusal of the table will indicate that supplier panelists have considerably less enthusiasm for electro-mechanical and LED instrumentation than do the OEM panelists, and supplier panelists appear to favor numeric and analog displays.

Display Technology	2000	
	OEM	Supplier
Analog	70%	60%
Digital	20	30
LED	10	5
Electro-mechanical	50	30

TREND FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table with the demise of mechanical instrument panels, various types of electronic analog/digital display technologies will dominate.

Display Technology	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Electronic Analog IP	40%*	70%	50%*	75%
Electro-mechanical IP	20	50	20	40

* Delphi V forecasts are a summation of both "Electronic Analog IP Displays" and "Electronic Analog (digitally implemented) IP" categories.

STRATEGIC CONSIDERATIONS

While there has been considerable promotion of electronic instrumentation displays as the wave of the future, Delphi VI panelists forecast that a large percentage of the market will remain electro-mechanical well into the next century. With respect to the electronic formats, vacuum-fluorescent displays (VFD) are forecast to be the preferred. The predominance of electro-mechanical displays may be due to a combination of higher cost and lower reliability of the electronic displays. It is of interest to note that current Delphi forecasts indicate that analog displays will predominate over numeric displays even though current human factors research clearly indicates that electronic digital displays are easier to read, especially for older drivers. There are reports, however, that the continual updating of the electronic displays are disturbing to the driver when viewed peripherally. Driver preference for numeric displays often occurs after extended analog use. Therefore, it may be some time before a significant market penetration for these technologies occurs.

The data for speed display format forecast also indicates a strong preference for analog (pointer) over numeric (digital) display. Human-factors tests have generated numerous complaints from participants, particularly among elderly drivers, regarding the flashing of numeric digital displays during the changing of representations. These considerations are indications of consumer wants and needs. When aspects of vehicle quality, reliability, and durability are a given, attention must be given to consumer ergonomic preferences. These factors could well be the competitive edge.

TECH-40. What percentage of NAPP cars will incorporate the following driver information systems in the years indicated?

Vehicle Interior Developments	Median Response		Interquartile Range	
	1995	2000	1995	2000
Navigation & travel/trip area				
Motorist information (Shows gas stations, restaurants)	1%	5%	1/2%	2/7%
Navigation systems ("Here are the local roads")	2	5	1/2	3/10
Orientation systems ("You are here")	2	5	1/2	3/10
Route guidance ("Here is how to get there")	2	5	1/2	2/5
Traffic information (Shows congestion)	2	5	0.5/2	2/10
Trip planning ("There are different ways to get there")	2	3	1/2	2/5
New seating developments				
Personalized, programmable-contoured seats	2%	5%	1/4%	2/10%
Driver interface				
Voice-operated controls				
Cellular phones	5%	15%	2/20%	5/20%
Voice output to driver	1	2	1/2	1/5

SELECTED EDITED COMMENTS

- Almost all cars can have more than one driver, thus, I cannot see too much market for personal seats.
- I expect legislation in this area due to perceived accident rate.
- Intelligent Vehicle Highway Systems (IVHS) will be slow in coming. As a result, traffic information will not catch on for a while.
- The level of incorporation will be influenced by the success of IVHS and federal support.
- Navigation and travel information will not be much of a factor in the next ten years because of cost and underdeveloped software (incomplete information for the driver).
- We need to have an agreed upon national/international format soon.
- New generation voice synthesis and recognition chips are close to reality.
- Nothing in this list will be of any significance, except possibly cellular phones if they become original equipment.
- The entire area of IVHS is moving steadily; it is further along in Japan and Europe. There are real forces driving it; and it will develop rapidly once institutional barriers are managed.
- Traffic information will be more difficult because of the coordination required to achieve it.
- Traffic information will lag due to infrastructure requirements.
- Voice output can be considered to be annoying and non-value added.
- Voice output is only a minimum benefit unless provided as part of a voice input/output system.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in agreement regarding the application of vehicle interior developments in NAPPVs.

The manufacturer and supplier panelists are also in agreement on the percentage of North American-produced cars that will incorporate driver information systems in the year 2000. It is interesting to note that there is a minor degree of disagreement regarding the application of these technologies in the year 1995. There is a consistency in the variances: the Supplier panelists forecast a median of 1% for all "Navigation and Travel/Trip" driver information systems in 1995; whereas the OEM panelists present a median forecast of 2% for the same information systems. All other 1995 forecasts are identical.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

While there may be significant geographic penetration of Intelligent Vehicle Highway Systems (IVHS) by the year 2000, it will not be widespread. This is in sharp contrast to Japan where there are now at least 250,000 vehicles with navigational and IVHS systems in operation. This may be due in part to Japan's relatively more advanced infrastructure to support traffic information systems and the existence of necessary motorists' information data bases. However, this dependency on data bases is not a requirement for many independent IVHS systems and, therefore, should not inhibit an increasing utilization of the systems surveyed.

The forecasts of the Delphi panelists also suggest the entrance into the market of voice-control systems other than cellular car phones. The significant increase in cellular phone forecasts for the year 2000, (see TECH-42), suggests profit opportunities for the OEMs and the aftermarket, although problems of network compatibility and range limits appear to continue to inhibit more extensive application.

There continues to be a lack of supporting human-factors research data in this area. This could be a major factor relating to a lack of increasing application of the various IVHS technologies. It is apparent, however, that there is some demand for these systems, particularly in niche markets such as rental car fleets.

TECH-41. What percentage of NAPPVs will incorporate the following display technology in the years indicated?

Display Technology	Median Response		Interquartile Range	
	1995	2000	1995	2000
Head-up displays (HUD)	2%	5%	1/2%	3/10%
Virtual-image displays (VID)	1	4	1/2	2/10

SELECTED EDITED COMMENTS

- Head-up display could benefit older population.
- There will be little impact of primary VID or HUD. We will get back to basics with low-cost, high-reliable, electronic-analog usage.
- The Japanese are pushing their technologies. The Tokyo Auto Show 1991 should be an indication.
- These are distracting and not worth the cost and effort.
- Usage of HUD and VID will be rare.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists' forecast for HUD in 1995 are identical at 2% and are consistent with the median. For the year 2000, the OEMs project 7%, and suppliers forecast of 5%.

COMPARISON OF FORECAST: MKT-34

The Marketing panelists forecast the penetration rate of HUD for the total U.S. passenger-car market (domestic and import). Although not precisely comparable to the Technology panelists' forecast for NAPPVs, the forecasts of the two panels are very close: the Marketing panelists forecast for HUD in 1995 is 3% and 5% in the year 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table, although there was a significant decrease in the forecasted percentage application of HUD for 1995 from Delphi IV to Delphi V, the current forecasts for both 1995 and 2000 are consistent with the 1989 Delphi .

Display Technology	Forecast by 1995			Forecast by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Head-up display	8%	2%	2%	5%	5%

STRATEGIC CONSIDERATIONS

It is clear from the current Delphi panelists' forecasts that HUDs will not realize widespread usage, even though they are needed for some IVHS applications. One reason may be that problems related to adequate daytime legibility remain to be solved. VIDs, intended to aid older drivers, are also expected to see limited application. Essentially, the safety advantages afforded by these displays are perceived to be small.

TECH-42. What percentage of NAPPVs will incorporate cellular phones in the mode indicated?

Cellular Phone Operation Mode	Median Response		Interquartile Range	
	1995	2000	1995	2000
Manual	10%	20%	5/20%	10/30%
Voice-operated	3	10	2/5	5/20

Of the above total percentage of cellular phones, what percentage will be OEM- or aftermarket-installed?

Installation Method	Median Response		Interquartile Range	
	1995	2000	1995	2000
OEM	10%	30%	5/20%	15/50%
Aftermarket	90	70	80/95	50/80

SELECTED EDITED COMMENTS

- Aftermarket costs are so low that the OEM installations will be seriously limited.
- Breakthroughs in cost and performance of very small, portable, cellular phones could reduce the automotive installation.
- Car phones are a major safety debit. I will be happy to see them banned.

MANUFACTURER/SUPPLIER COMPARISON

The two groups of panelists are in very close agreement on the percentage of incorporation of cellular phones in NAPPVs. The only differences are for 1995: OEMs forecast 10% for manually operated and 2% for voice operated. The suppliers forecast is for 15% and 4%, respectively.

COMPARISON OF FORECAST: MKT-34

The Marketing panelists were asked to forecast percentage application in total U.S. passenger-car market (domestic and import) for factory-installed cellular phones. The Marketing forecast is 10% for 1995 and 20% for the year 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

As is demonstrated in the following table, the percentage forecast of 1995 NAPPVs incorporating cellular phones decreased from 15% in the 1987 Delphi IV to 5% in the 1989 Delphi V; but there is a sharp rebound in 1991, approaching the 1987 forecast. The forecast for the year 2000 in Delphi VI is twice that of the previous Delphi. The forecasts for Delphi VI noted with an asterisk (*) represent a total of manual and voice-operated cellular phones. This distinction was not made in previous Delphi surveys.

Cellular Phone	Forecast Usage by 1995			Forecast Usage by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
	15%	5%	13%*	15%	30%*

STRATEGIC CONSIDERATIONS

Car cellular phones are beginning to escape the rare-option category and are becoming a critical feature for many drivers. It is clear that an overwhelming majority of phones will be manually operated despite the safety advantages afforded by voice-operated phones. Mobile phone use should continue to grow as specialized services for cellular users are provided. In addition, cellular phones are increasingly being viewed as a personal safety item, (e.g., vehicle breakdown and 911 calls).

However, some impediments to increasing utilization remain. There is the failure to integrate the network system in different geographical locales to extend limited functional range. Additionally, there are design problems with regard to the size of the key pad, as well as numerous perceived safety problem associated with phone operation while the vehicle is in motion.

It is also apparent from the panelists' forecasts regarding installation methods that cellular phones will remain primarily an aftermarket option rather than an OEM option. This may be due to the failure of the OEM designers to ergonomically integrate cellular phones with passenger interior formats.

TECH-43. What percentage of NAPPVs will have the following entertainment systems in the years indicated?

Entertainment Systems	Median Response		Interquartile Range	
	1995	2000	1995	2000
Standard cassette	50%	40%	40/70%	20/70%
Compact disc (CD)	10	30	5/20	20/45
Digital audio tape (DAT)	5	15	1/10	5/30
Broadcast TV (for driver)	0	1	0/1	0/2
VCR (for driver)	0	0	0/0	0/2

SELECTED EDITED COMMENTS

- TV and VCR for the driver will be too much of an issue of safety.
- Visual images would be seen as distracting and would be controlled by legislation.
- Whose idea is it for videos for the driver? That is very unsafe.

MANUFACTURER/SUPPLIER COMPARISON

The only significant difference between the two groups is with respect to the percentage of installation of standard cassette entertainment systems. The OEM panelists forecast 65% in 1995 and 50% by the year 2000. The Supplier panelists forecast 50% in 1995 and 30% by the year 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Compact disc players (CDs) have not, and according to panelists forecasts, will not, take over the market as some observers have predicted. This may be the result of the significant consumer investment in the cassette tape media, handling problems associated with CDs while driving, and the price of the units.

Watching TV while driving is illegal in many states. It appears that TV and VCR output to the driver will be rare.

VII. SAFETY FEATURES

TECH-44. What percentage of NAPPVs will incorporate driver and front passenger air bags in 1995 and 2000?

Air Bag Applications	Median Response		Interquartile Range	
	1995	2000	1995	2000
Driver side				
For forward impact	70.0%	98%	60/80%	95/100%
For side impact	1.0	10	0/5	5/20
Passenger side				
For forward impact	30.0%	80%	25/50%	70/100%
For side impact	0.1	5	0/3	3/20
Rear seat occupants	0.0	3	0/0	0/10

SELECTED EDITED COMMENTS

- Air bags (passenger/driver) are likely to be standard on all vehicles before 2000.
- Driver-side air bags will be required. Side impact will be delayed.
- Motorized belts will die--but not fast enough.
- Safety and environment will sell in the 1990s. Air bags are a must, especially if we downsize for fuel economy.
- Side-impact air bags are possible, but technical hurdles are too large at the present to predict use.
- Side-impact air bags will have to be legislated.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are essentially the same.

COMPARISON OF FORECAST: MKT-36

As reflected in their respective forecasts, there is a surprisingly divergent of opinion between the Technology and Marketing panelists regarding air bags. The following table illustrates this trend.

Air Bags	Technology Panel		Marketing Panel	
	1995	2000	1995	2000
Driver side	70%	98%	30%	80%
Passenger side	30	80	10	40

TREND FROM PREVIOUS DELPHI SURVEYS

While there are differences in the manner the air bag question was presented in previous Delphi surveys, there is a dramatic increase in the forecasts for air bag applications. It appears that this increase may be due to the belief on the part of the Delphi VI panelists that air bags will be either market-driven standard equipment or legislatively mandated (as a replacement for passive belt systems) by the end of this decade.

Air Bag Placement	Forecast Usage by 1995			Forecast Usage by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Driver only	10%*	20%**	70%	30%**	9%
Passenger side	N.A.	20	30	40	80
Rear-seat occupant	N.A.	0	0	2	3

*Total air bags. Not specified in Delphi IV.
** Specified in Delphi V as "Driver and front passenger."
N.A. = not asked

STRATEGIC CONSIDERATIONS

Dramatic growth is forecast for the application of both driver and passenger side air bags in future light-duty passenger vehicles. Expectations for air bag use for the driver only for the year 2000 are approximately 40% in Delphi V; they are 98% in Delphi VI. This means that driver air bags will be essentially a standard feature. At the same time, we have seen a dramatic increase in interest for passenger-side air bags. Also, there is surprising interest in air bags for rear-seat passengers. In addition, there is support for the use of air bag technology for side-impact protection, although the interquartile range is very broad, suggesting a high level of uncertainty.

The growing consumer enthusiasm for air bags is clearly evident. There are still important issues that must be resolved with air-bag technology, including cost. Also many consumers still believe air bags as a supplementary restraint are adequate in themselves without the use of seat belts and shoulder harnesses. It is still conceivable that as customers become more knowledgeable of the overall safety improvements achieved with seat belt and shoulder harness, they may question the added cost of air bag technology. The industry is obviously increasing its confidence in the use of air bags and is incorporating them in practically all future designs.

When looking at the general topic of safety and passenger protection on a systems level, it is intriguing to think of how a so-called passive, friendly interior will mesh with belts, side- and forward-impact air bags, and other features of the vehicle. With continuing cost pressures, a true systems approach may yield more cost-effective restraint systems than we have at the present time. We must follow this area closely because the chances for surprises are high, as are the likelihood for new legislation and regulation.

TECH-45. What percentage of air bag sensors in NAPPVs will be either mechanical or electronic by the following years?

Air Bag Sensors	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Mechanical air-bag sensors	80%	30%	10%	50/90%	10/50%	0/30%
Electronic air-bag sensors	20	70	90	10/70	50/90	70/100

SELECTED EDITED COMMENTS

- Few OEMs will want to explain in court why they took the inexpensive alternative in an injury lawsuit.
- It will all be electronic.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in agreement.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

There appears to be some controversy with regard to impact sensing with air bags. Generally, the panelists believe that there will be a steady, consistent trend to electronic-based rather than mechanical sensors. As the comment about potential liability suggests, failure to deploy or inadvertent deployment of the air bag can have grave consequences. Basically, technologies such as this must be fully validated before they are exposed to the consumer. The next general trend toward electronic sensing is consistent with the overall trend in vehicle control. However, we must observe that it may be a mistake to totally write off mechanical devices since they can be made very simple, nearly foolproof, and perhaps less expensively. This looks like an area where both mechanical and electrical engineers will engage in heated competition during the next few years.

TECH-46. What percentage of NAPPVs will incorporate the following safety features by the year 2000?

Safety Features	Percent NAPPVs	
	Median Response	Interquartile Range
Backup collision alarm	5%	2/5%
Blind spot collision warning system	5	2/5
Forward collision warning system	5	1/5
IVSAWS (In-Vehicle Safety Advisory Warning System)	3	1/5
Automatic headway control	1	0/1
Radar braking	1	0/1
TV cameras and CRTs instead of mirrors	1	0/1
Ultra-violet (UV) headlights	1	0/1
Automatic steering system override (to prevent skids)	0	0/0
Infra-red (IR) vision systems	0	0/1

SELECTED EDITED COMMENTS

- Cost will be a big factor. Value will be questionable on most of the above.
- Cost/benefit ratio is poor on most of these items.
- You cannot take away control from the driver.
- I believe technology that takes control of vehicle away from driver into an automatic mode will be next to impossible to sell.
- Many of these features will be influenced by the success of IVHS and federal and state support.
- Seat-belt tension-control systems will be developed to replace the inertia systems that have recently cost GM a lot of money in lawsuits.
- The U.S. legal/liability climate will delay much IVHS technology on automatic steering-system override and radar braking.
- Value and complexity as well as potential legal problems in case of malfunction will restrain use of these items.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

A host of safety features is considered in this question, ranging from automatic headway control and back-up collision alarm to infra-red vision systems and radar braking. Generally, the panelists foresee only very limited penetration of these technologies and in some cases, none at all, such as with override systems to take on steering responsibility or infra-red vision systems. In most cases, electronics is a key enabler and in most instances, the technology appears feasible. The primary issues are related to such important considerations as cost, the *value* perceived by the consumer as a function of that cost, and system reliability.

Of course, many are concerned with the complexity of present day and future vehicles. The fact that consumers may already be at an overload point in terms of cost may require rethinking of various technological strategies to ensure there is sufficient value represented by new features. An interesting point raised in the comments suggests that any attempt to take control of the vehicle away from the driver will be next to impossible to sell. It is probably appropriate considering the present state of technology and the consumer. Also it is crucial to look at a number of these factors with regard to the developing role

of IVHS, which seems to be gaining momentum. All in all, these technologies are potentially significant and should be watched closely as more complex and sophisticated vehicle safety systems emerge in the years ahead.

VIII. POWERTRAIN/DRIVETRAIN

TECH-47. Many industry experts expect substantial powertrain changes in view of the newly mandated Clean Air Act. What major changes, if any, do you expect in each of these areas?

DISCUSSION

Virtually all the panelists gave multiple responses to this question. Many times different terminology was used to describe the same technological change. The following tables represent the reduction of these varied responses to individual categories. In engines, for example, multi-valve encompasses 3-, 4-, and 5-valve engines. Additionally, the categories are not necessarily mutually exclusive. For example, improved fuel management or lean burn technology could operatively be included in increased electronic controls. The separate categories for those technological changes reflect specificity on the part of the panelists. Results are expressed as percentages of total panelists who responded for a particular category. The varied responses (as well as single responses) can be seen in *Representative Responses*. This categorization will also apply to Transmission and Exhaust Systems.

ENGINE

Engine Major Changes	Percentage of Panelists
Multi-valve	21%
Improved fuel management	35
Downsizing (displacement reduction)	16
Variable valve timing	16
Increased electronic controls	15
Electric car	15
Flexible fuel capability	13
Friction reduction	13
Lightweight materials	10
Two-cycle engines	10
Reduced pumping losses	7
Re-introduction of diesel engines	7
Improved ignition	4
Overhead cams	4
Lean burn technology	4

REPRESENTATIVE RESPONSES

- More precise electronic control of fuel/air ratio, more turbocharging.
- Lightweight materials such as aluminum blocks and heads.
- Sequential port injection on all engines, a significant increase in computer controls of spark and fuel.
- More 4-valves/cylinder, OHC engines, increased use of multi-point, sequential fuel injection.
- Lower displacement, friction and idle speeds, variable cam timing.

TRANSMISSION

Transmission Major Changes	Percent of Panelists
More speeds: five- and six-speed automatics	48%
Increase in electronic controls (vs. hydraulic)	41
Continuously variable transmissions (CVTs)	9
Reduction in parasitic losses	9
Higher efficiencies	7
No change	4

REPRESENTATIVE RESPONSES

- Continuation and acceleration of the trend to electronic (instead of hydraulic) control.
- Increase in six-speed manuals and five-speed automatics.
- More electronics for reduced shift variation and increased self diagnostics.
- CVTs with regenerative braking.
- Higher speed ratios, higher torque capacity.

EXHAUST

Exhaust System Major Changes	Percent of Panelists
Pre-heated catalysts	26%
Reduced back pressure	24
Close coupled catalysts	20
Improved catalytic convertor (unspecified)	18
Electronic noise cancellation (related to reduced back pressure)	14
Modified oxygen sensors	6
None	2

REPRESENTATIVE RESPONSES

- Double-walled, insulated, take-down pipes to close coupled convertors.
- Catalytic converters moved closer to the exhaust manifolds.
- Active catalyst monitoring, better catalyst light-off through heating.
- Free flow electronic mufflers.
- Rapid light-off converters.

STRATEGIC CONSIDERATIONS

Clearly, the new Clean Air Act will require significant changes in future powertrains. All systems are expected to be impacted, including the base engine, exhaust system, and transmission. The implications of the suggested changes are significant in the industry for a variety of reasons, including product cost, availability of human resources to implement change, capital, and system complexity. Some of the suggested changes, however, would probably occur anyway because of advances being made for other reasons, including international competition, new technology, and the major extent of powertrain redesign scheduled before the new Clean Air Act was passed.

One significant implication of the changes is that all manufacturers may not be equally capable of developing and implementing the technology required. The knowledge and technology level in powertrains is about to increase and those with lesser capabilities could experience significant competitive disadvantage.

One general concern related to the new technology that is being considered to ensure compliance with the new Clean Air Act is the fact that little impact will be evident in atmospheric pollution levels for years to come. The major automotive-related emission problem today is not the new vehicle, but old and/or poorly maintained in-use vehicles. As a general rule, approximately 20% of existing vehicles cause about 80% of the problem. A more cost-effective approach, and one that would yield far quicker results, would address in-use problem vehicles far more aggressively. We are aware that the political problems of such an effort are significant because of the required direct contact between the customer (voter) and government, but if the problem is to be addressed cost effectively, there are few options. Furthermore, if the cost of new vehicles increases, even modestly, as a result of improved emission controls, (thus deferring purchases of new vehicles and causing retention of high polluters in the fleet), then the overall pollution problem could worsen. The policy implications of the new Act would appear less than fully developed.

All things considered, significant powertrain changes are expected that will compete with other areas of the vehicle for financial and human resources. Still, suppliers of appropriate technology will likely benefit, even as suppliers of older and potentially obsolete technology are vulnerable.

TECH-48. What percentage of NAPPV engines will be equipped with the following number of cylinders in 1995 and 2000?

Number of Cylinders	Median Response		Interquartile Range	
	1995	2000	1995	2000
Passenger Cars				
3 Cylinders	0%	3%	0/2%	0/8%
4 Cylinders	45	51	43/50	41/55
6 Cylinders	40	35	35/40	30/40
8 Cylinders	15	11	15/16	9/15
10 Cylinders	0	0	0/0	0/0.1
Light-Duty Trucks				
3 Cylinders	0%	0%	0/0%	0/0%
4 Cylinders	15	20	15/18	15/25
6 Cylinders	50	50	45/50	45/55
8 Cylinders	35	30	35/38	25/35
10 Cylinders	0	0	0/0	0/0

SELECTED EDITED COMMENTS

- We will see more supercharging with smaller engines to get both performance and economy.
- My answer assumes a 30/35 m.p.g. CAFE for passenger cars and 25/30 m.p.g. CAFE for light trucks.
- Ten-cylinder vehicles will represent a small percentage, much less than 1%.
- We should consider five-cylinder engines for 2000.
- Light duty trucks will be forced to downsize.
- V-12s probably are worth including. You will see more of them than 10-cylinder engines.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

Number of Cylinders	Forecast Usage by 1995			Forecast Usage by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Passenger Cars					
3 Cylinder	2%	0%	0%	1%	3%
4 Cylinder	50	50	45	47	51
6 Cylinder	35	30	40	35	35
8 Cylinder	13	20	15	17	11
10 Cylinder	N A.	0	0	0	0
Light-Duty Trucks					
4 Cylinder	45%	14%	15%	15%	20%
6 Cylinder	35	30	50	50	50
8 Cylinder	20	36	35	35	30

N.A. = not asked.

STRATEGIC CONSIDERATIONS

The forecast of mix of engine cylinder configurations has changed little over the last three Delphi forecasts, although there is a general strengthening of expectations for six-cylinder engines for both passenger cars and light trucks. In addition, there is renewed expectations for a very modest number of three-cylinder engines by the year 2000. In some respects, it seems surprising that expectations for four-cylinder engines have not increased markedly, particularly considering anticipated higher CAFE standards. This would appear to indicate that on the one hand the industry is improving its ability to make more efficient engines, but on the other hand the market will continue to demand power even with the more restrictive CAFE standards. In general, a reasonable balance is forecast in the engine mix with no sharp swings in cylinder configuration evident even with the magnitude of overall engine redesign forecast.

If the government were to mandate high levels of CAFE such as recommended in the Bryan Bill, we are confident that panelists would considerably expand their expectations for three- and four-cylinder designs. Clearly, the present forecast appears to be based more on the expectations of CAFE standards in the area of 28-32 m.p.g. during the 1990s.

Following the trend of past Delphi forecasts, light-duty trucks and vans are expected to be equipped with a somewhat greater average number of cylinders per vehicle than passenger cars.

It would be a mistake to infer from these relatively stable forecasts that engine technology will remain constant for the next few years. The substantial forecast for total engine redesign during the remainder of this decade indicates otherwise (see TECH-52).

TECH-49. What percentage of those six-cylinder engines will be V-6 and what percentage will be in-line (I-6)?

Engines	Median Response		Interquartile Range	
	1995	2000	1995	2000
Passenger cars				
V-6	90%	90%	45/90%	40/95%
I-6	10	10	5/20	5/20
Light-duty trucks				
V-6	75%	80%	46/80%	50/90%
I-6	25	20	10/40	10/30

SELECTED EDITED COMMENTS

- In-line could make a come back if T-drive configurations are developed.
- We will see more family engine designs, but you could have in-line-families and V-families.
- Packaging requirements will influence V-6 usage.
- Wider use of I-6 depends on unique transverse packaging for compactness.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are essentially the same.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Because of recent speculation on engine cylinder configurations for six-cylinder designs, we asked a question with regard to future mix between in-line and V-bank arrangements. A few years ago, it was generally accepted that the in-line engine was obsolete because of problems with safety in the fore and aft position and with packaging when transversely mounted. However, with research on T-drive and growing popularity of the in-line-six on the international scene, it would appear there is modestly growing interest in this configuration for passenger cars and more so for light-duty trucks. The data does not suggest a revolution in six-cylinder configuration. However, the comments offered in this question are particularly pertinent to the issue.

It should be noted that with the current uncertainty with regard to engines, including that of cylinder configuration, trends should be watched carefully, in particular, the technology of the In-line six with T-drive. Prototype designs demonstrate a considerable reduction in the length of the engine compartment and, therefore, size and overall mass of the vehicle.

TECH-50. On a percentage basis, indicate the mix of spark-ignited engine displacements you expect in North American-produced passenger cars made in MY 1995 and 2000.

Displacement in Liters	Median Response		Interquartile Range	
	1995	2000	1995	2000
5.1+	1.0%	0.5*%	1/2%	0/1%
4.1-5.0	11.0	8.0	10/13	5/10
3.1-4.0	30.0	29.0	29/32	25/31
2.1-3.0	40.0	40.0	37/40	35/43
1.5-2.0	18.0	20.0	15/20	18/25
Below 1.5	0.5	3.0	0/2	1/5

*Forecast of less than 1.0% are not factored into the total.

SELECTED EDITED COMMENTS

- Displacement will be slightly reduced but power density will increase and number of cylinders in low displacement engines will increase.
- Distribution depends on CAFE. If we have 40 m.p.g., we must downsize to European and Japanese size (i.e., 1.5-2.0 L).
- While displacement will decline, power will increase with improvements in induction, turbocharging, fuel management, and combustion control, and through the increased use of two-cycle powerplants.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are essentially the same.

TRENDS FROM PREVIOUS DELPHI SURVEYS

NAPP Cars Displacement in Liters	Forecast Usage by 1995			Forecast Usage by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
5.1+	2%	3%	1.0%	2%	0.5%
4.1 - 5.0	10	18	11.0	16	8.0
3.1 - 4.0	26	21	30.0	21	29.0
2.1 - 3.0	36	50	40.0	51	40.0
1.5 - 2.0	21	10	18.0	10	20.0
Below 1.5	5	0	0.5	0	3.0

STRATEGIC CONSIDERATIONS

Compared with Delphi V, expectations for 4.1+ liter engines have decreased, increased for 3.1 - 4.0 liters, decreased for 2.1 - 3.0 liter, and increased again for 2.0 liter or lesser displacement designs. On the surface, the changes would appear to be somewhat surprising. However, on further inspection, it appears that increases in specific power through multi-valve and overhead cam designs will permit downsizing of the average engine displacement while maintaining a given power output. This suggests that four, six, and eight cylinder displacements will be shifted to the next lower displacement categories. As evidence of this, for example, consider the new Ford modular engine, which replaces an engine of considerably greater displacement. It should be noted that this improvement in specific power may not be due only to the application of four-valve, double overhead cam technology. Substantial improvements have been made in push-rod designs with changes in materials, increased manufacturing precision, and other technological advances with seemingly old-fashioned designs.

In addition, the expected downsizing is undoubtedly influenced by expectations for higher CAFE standards. In general, it should be noted that domestic manufacturers have greater flexibility with regard to engine displacement since most foreign manufacturers build engines for use in foreign countries with heavy taxation and/or high license fees on larger

displacement designs. Consequently, both European and Japanese engines place a premium on smaller specific output whereas the North American manufacturers have the option of utilizing greater displacement to achieve the same overall performance level. A major uncertainty for engine displacement remains with respect to future energy price/availability issues and cost and complexity of high specific-power technology. It is probable that American manufacturers, on the average, will utilize larger engines but with reasonable increases in specific output.

One continuing important point with regard to engines is the role that customer expectations will play. It appears that customers, in general, are more concerned with the function provided than how that function is achieved. Market forces will undoubtedly be a key factor in the sizing of future engines as well as CAFE and emissions standards. The overall uncertainty related to engine sizing and technical features will be high during the coming decade.

TECH-51. On a percentage basis, indicate the mix of spark-ignited engine displacements you expect in North American-produced light-trucks and vans made in MY 1995 and 2000.

Displacement in Liters	Median Response		Interquartile Range	
	1995	2000	1995	2000
5.1+	25%	20%	20/26%	15/22%
4.1-5.0	30	29	28/31	23/30
3.1-4.0	20	21	17/20	20/25
2.1-3.0	24	28	24/26	24/30
1.5-2.0	1	2	1/2	1/5
Below 1.5	0	0	0/0	0/0

SELECTED EDITED COMMENTS

- Large truck engines are difficult to forecast as diesels will probably replace the larger gasoline engines, particularly in commercial applications. In Europe diesel is 100% of larger light-vehicle applications.
- There will be a trend toward small, personal use recreational vehicles (Tracker, Sidekick, etc.) which will push displacement downward.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a recent previous Delphi survey.

STRATEGIC CONSIDERATIONS

A stable future is predicted for engine displacement in light trucks and vans through the decade of the 1990s. In general, the displacement expectations are somewhat greater than for passenger cars, because of larger average vehicle size and greater power requirements. However, increasing use of smaller sport/utility vehicles could skew the data somewhat toward smaller engine sizes in the future and there is modest evidence of this with increasing expectations for both 1.5-2 liter and 2-3 liter sizes. It would appear that truck engine displacement mix will be more predictable than for passenger cars. However, aggressive CAFE regulations could have a major impact on truck engine displacement, although probably not to the extent of passenger cars.

TECH-52. What percentage of current North American-produced engines will be fundamentally redesigned by 2000?

Engine Type	Percent NAPPV Engines Redesigned	
	Median Response	Interquartile Range
4-cylinder	65%	60/75%
V-6	60	60/75
V-8	50	40/70

SELECTED EDITED COMMENTS

- Everything will be substantially redesigned.
- I assume adoption of most stringent federal requirements currently under discussion for CAFE.
- Higher specific power at higher r.p.m.; improved efficiencies will prompt new engines.
- Multi-valve heads and all aluminum construction engines will be "fundamentally redesigned."
- Interpretations of fundamentally redesigned engines include two-stroke combustion process, variable valve timing/overlap, ceramic pistons or cylinder liners, manifolds, composite connecting rods, and stratified charge heads/manifolds, multi-spark, etc.
- It is important to remember that 1996 engines are essentially committed. Engineering can only contain about 40% new designs in a 10-year period with current economics. It will be more like 30%.
- Legislation will force maximum efficiency engines.
- Major improvements are necessary to meet emissions and CAFE legislation.
- There will be some in-line engines (primarily six-cylinder, but also five-cylinder and some eight-cylinder).
- V-6s will not be changed as much as four- and eight-cylinders; they will be the "bread and butter" engine of the 1990s.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TRENDS FROM PREVIOUS DELPHI SURVEYS

The table below presents comparisons between Delphi V and Delphi VI. Please se Strategic Considerations.

Engine Type	NAPPV Engine Redesign	
	Forecast Usage by 2000	
	1989 Delphi V	1991 Delphi VI
4-cylinder	70%	65%
V-6	65	60
V-8	60	50

STRATEGIC CONSIDERATIONS

Generally, there is a modest reduction in expectations for fundamental redesign of engines during the 1990s compared with Delphi Vs forecast. This, in part, may be due to the fact that a number of the engines had already been redesigned in the early 1990s. Furthermore, it may reflect changes in thinking with regard to engine technology. Considerable refinements to conventional push rod engines are being made that have led to substantial improvements in both performance and fuel economy. The general increase in manufacturing precision of "old tech" designs has led to some real surprises. It may also reflect growing capital shortage in the industry. Capital requirements are extraordinarily high, and unless engine redesign is absolutely dictated by market forces, manufacturers may be increasingly reluctant to redesign engines because of the enormous cost involved. In any event, this will be an exciting area in the years ahead. The level of redesign suggested still represents a significant investment by the manufacturers. The competition for capital from other areas of the vehicle is likely to

be intense. Consequently, this trend should be watched closely by all suppliers even those of non-powertrain related components.

TECH-53. What percentage of NAPPVs will be equipped with diesel engines in 1995 and 2000?

NAPPV with Diesel Engines	Median Response			Interquartile Range	
	Est. 1990 MY	1995	2000	1995	2000
Passenger cars	0.0%	0%	2%	0/1%	0/5%
Light trucks/vans	7.0	9	11	7/10	10/15

SELECTED EDITED COMMENTS

- Emissions requirements make this decision unclear.
- Fuel economy and emissions are at odds here.
- There are still many disadvantages to diesel. An increase in diesel applications will happen only if fuel costs rise significantly, and diesel fuel is a bargain. Gasoline engines have closed the fuel economy gap.
- Clean air legislation will definitely hurt diesels. Other alternatives will be found.
- Do not count diesels out in the rest of the world. California Air Resources Board (CARB) rules may kill it in the United States.
- If noise and emissions problems are solved, percentage would double.
- I am not aware of any passenger car diesel program with much activity.
- Cheap gasoline and diesel particulate standards will limit the market for diesel engines in NAPPVs. However, there will always be the "macho truck driver" segment that will want the same kind of engine that is used in Kenworths and Peterbilts.
- Emissions will ultimately kill diesels.
- We will probably see alternate fuel diesels.
- Particulate emission laws will cause the diesel to all but disappear.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer/supplier panelists are in agreement regarding their forecasts for diesel engines in NAPPVs.

TRENDS FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table, a modest resurgence in diesel engines is forecast by the end of this decade. The previous Delphi forecasts for 1995 seemed to indicate a lack of enthusiasm for the diesel engine in the North American market. However, it is clear that while emissions problems continue to represent an obstacle, the issue of fuel economy continues to drive the probable utilization of diesel engines not only in light trucks and vans, but also in passenger cars.

NAPPVs with Diesel Engines	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Passenger cars	3%	0%	0%	0%	2%
Light Trucks/vans	15	3	9	3.5	11

STRATEGIC CONSIDERATIONS

The expected penetration of diesels in the passenger car market remains low, although 2% is forecast in the year 2000. On the other hand, there are increasing expectations for the diesel in light trucks and vans although even by the year 2000, the forecast just barely exceeds 10%. There are some major uncertainties with regard to the future use of diesel engines, several of which are discussed in the comments section of this question. The ability of the diesel to satisfy future emissions standards (particularly NO_x and soot emissions), is in doubt even as the possibility of tough new CAFE requirements would appear to make the diesel more attractive. Furthermore, we believe the rather limited enthusiasm for diesels may be related to the negative experiences of the early 1980s.

Also, gasoline engine fuel economy improvements have been significant enough to slow the progress toward diesels. Research obviously is continuing on diesel engines, and particularly important progress has been made in Europe. Still, the prospects for the future of diesel engines in North America in light-duty vehicles are limited even though they are greater than had been forecast two years ago.

TECH-54. What percentage of NAPPVs will use two-cycle gasoline engines in the years 1995, 2000, and 2005?

NAPPVs Using Two-Cycle Gasoline Engines					
Median Response			Interquartile Range		
1995	2000	2005	1995	2000	2005
0%	5%	7%	0/1%	2/5%	5/10%

SELECTED EDITED COMMENTS

- The two-cycle engine probably will not make it, but if it does, it could be 25-50% by 2005.
- It depends on emissions legislation.
- Usage is dependent on being able to meet the new emissions requirements. Current estimates are that they can be met but it will be difficult (invention required for California).
- Automakers are currently protecting their positions. Success rate is still too foggy to predict.
- The next two years will tell if Orbital and others can do it.
- The technical jury is still out on two-cycle. Numbers could be very large if it works.
- There are no active two-cycle programs with a realistic chance of production by 1995.
- There will be limited applications in small cars only.
- I do not believe it can pass emissions durability in the 2000s.
- Two-cycles are highly dependent upon ability to meet NO_x standards and potential for improved fuel economy.
- Special fuel blends will be required for two-cycle engines.
- The downsizing of vehicles is driving higher power density requirements.

MANUFACTURER/SUPPLIER COMPARISON

The supplier panelists exhibit considerably more enthusiasm for two-cycle engines than the OEM panelists. The suppliers forecasts for two-cycle engines are 1% for 1995, 5% for 2000 and 10% for 2005; the OEM panelists forecast a considerable difference for the same years, respectively, 0%, 3%, and 5%.

TRENDS FROM PREVIOUS DELPHI SURVEYS

Although problems regarding emissions and capital investment remain formidable obstacles, incentives for two-cycle engines also remain strong. The increased forecasts of Delphi VI from Delphi V for the year 2000 appear to be representative of this interest on the part of both the manufacturers and suppliers (see Manufacturer/Supplier Comparison).

NAPPVs Using Two-Cycle Gasoline Engines				
Forecast Usage by 1995			Forecast Usage by 2000	
1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
3%	0%	0%	2%	5%

STRATEGIC CONSIDERATIONS

The role of two-cycle engines in North American light-duty vehicles remains uncertain, although expectations have expanded considerably compared with previous Delphi forecasts for the year 2000. Clearly, the incentives for the application of two-cycle engines remain high with advantages in packaging, weight, cost, possibly fuel economy, and other areas as well. Major problems remain with regard to exhaust emissions (particularly in light of new and more restrictive emissions standards) as well as engine durability. Hydrocarbon and nitrogen oxide emissions are difficult to control with the given operating characteristics of the engine, excess oxygen in the exhaust, low exhaust temperatures, and very short time for fuel/air mixing after fuel injection. Because of the potential advantages of this engine, most manufacturers in the world are pursuing aggressive programs to develop the technology.

The two-cycle could bring significant changes in vehicle configuration because of the small engine size. However, to take full advantage of the engine, a manufacturer would have to totally redesign the vehicle around the engine, and if the engine did not meet expectations in this vehicle, a conventional four-stroke engine in the same vehicle would not be easily packageable because of its larger size. We believe the two-cycle could be one of the most significant automotive developments of the 1990s and beyond. It must be watched very carefully by all associated with the automotive industry. Some suppliers would be directly affected (e.g., the valve component manufacturers), while others will be indirectly affected. It will be extremely interesting to watch the progress of this technology during the next few years.

TECH-55. What are the key problem areas inhibiting the introduction of two-cycle engines in NAPPVs?

Two-Cycle Engine Inhibiting Factors	Percent of panelists
Emissions	80%
Durability	22
Investment	20
Noise, vibration, harshness (NVH)	19
Fuel economy	13
Public perception	11
Displacement limitation	6

REPRESENTATIVE RESPONSES

- Combustion control: simultaneously satisfying emission and driveability requirements.
- Cost of all new retooling as opposed to using existing investments.
- Durability of fuel delivery systems.
- Emissions; durability issues; perception of consumers--"chainsaw" image; intransigence of automakers to adopt new technology.
- Nobody wants to be first.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Overwhelmingly, the Delphi panelists view emissions as their primary concern regarding two-cycle engines. This issue has been exacerbated with the passage of the new Clean Air Act and will probably be an uncertainty for many years to come. Emission problems may limit the vehicle size, since emission performance is proportional to the product of concentration of emissions multiplied by a mass flow rate proportional to vehicle size and mass. Concern was also expressed for durability, investment requirements, noise vibration and harshness (NVH), and other factors of lesser concern. From a purely technical standpoint, we view the durability challenge as more amenable to development than emission concerns. However, as noted in the Strategic Considerations of the prior question (TECH-54), powerful incentives associated with this engine require both manufacturers and suppliers to seriously consider the two-cycle as a contender. Because of the significant potential for competitive advantage, most who are working on two-cycle are reluctant (for proprietary reasons) to discuss it. We would expect significant developments in the technology within the next several years that could make the future of the two-cycle engine somewhat more clear.

TECH-56. What percentage of NAPPVs will incorporate the following advanced engine types in the years 1995, 2000, and 2005?

Engine Types	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Open chamber (D.I.) diesel	0%	2%	5%	0/1%	0/5%	0/10%
Stratified-charge spark-ignited	0	1	5	0/2	0/5	0/15
Low-heat rejection engine	0	1	2	0/1	0/6	0/10
Rotary combustion or Wankel	0	0	0	0/1	0/1	0/1
Gas turbine	0	0	0	0/0	0/0	0/1

SELECTED EDITED COMMENTS

- There will not be much penetration--risk and investment are too high here.
- Diesel engines will be in light trucks and vans only.
- Variable valve timing and lift will lead to improved diesel emissions.
- As we move to better fuel economy, some of the new engines are approaching these concepts. The problem is definitions.
- The Otto cycle (four-cycle, gasoline engine) will remain dominant.
- Nothing is really driving any of the above advanced engine types.
- Gas turbines may be applied in hybrids with electric batteries.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

Also, see discussion in Strategic Consideration.

Engine Types	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Open chamber (D.I.) diesel	5%	0.1%	0%	1%	2%
Stratified-charge spark-ignited	5	1.0	0	3	1
Low-heat rejection engine	2	0.0	0	2	1
Rotary combustion or Wankel	1	0.0	0	0	0
Gas turbine	0	0	0	0/0	0/0

STRATEGIC CONSIDERATIONS

Expectations for a variety of different internal combustion engines remain relatively low in the foreseeable future. However, by the year 2000 and 2005, modest growth is expected in the application of direct-injection diesel (D.I.) and stratified-charge, spark-ignited engines for light-duty vehicles. This forecast probably reflects the progress being made in these engine technologies, as well as expected demands for greater fuel economy considering the possibility of higher CAFE standards. As noted in our prior Delphi forecast, it is imperative to maintain a worldwide view of alternative power plants. Progress in such engines as the direct-injection (D.I.) diesel seems to be significant in some areas of the world, particularly in Europe.

The low-heat rejection engine is primarily associated with the diesel (because of octane requirement concerns due to high combustion chamber temperatures), and is generally thought to be more applicable to heavy-truck or commercial applications rather than light-duty vehicles. The high interquartile range for the D.I. diesel, stratified charge, and low-heat rejection engines suggests considerable uncertainty. A few panelists may, indeed, know something special. The rotary engine

is currently being produced by Mazda for its RX-7 but growth beyond that application seems to be limited. Finally, the vehicular gas turbine is still under development by several companies, but progress is slow. Furthermore, the conventional spark-ignited engine is proving to be a tough moving target.

Finally, it is imperative to note that possible, future, more restrictive emission standards may place a serious burden on all of these advanced powerplants. This issue must be looked at very closely before assessing the potential for these alternative engines in future light-duty vehicles.

TECH-57. What percentage of NAPPVs with spark-ignited engines will incorporate the following types of fuel-management systems in 1995 and 2000?

Fuel-Management Systems	Median Response		Interquartile Range	
	1995	2000	1995	2000
Fuel Injection				
Throttle body (single point)	30%	10%	20/35%	5/15%
Port (multi-point)	70	90	65/80	85/95
TOTAL	100%	100%		

SELECTED EDITED COMMENTS

- CAFE will dictate the incorporation of these systems.
- Emission standards will eliminate throttle-body injection on cars. Trucks will still have it.
- Multi-point may include direct cylinder injection by 2000.
- Precise fuel control will be the key issue for stringent tailpipe emission requirements.
- Soon everything will be port injection.
- There are no new U.S. throttle-body programs at this time.
- There will be developments of multi-point-type systems that use fewer injectors than total number of cylinders.

MANUFACTURER/SUPPLIER COMPARISON

There is some difference of opinion between the manufacturer and supplier panelists regarding their forecast for the percentage of incorporation of single point- or multi-point injection systems in NAPPVs.

Fuel-Management Systems	Forecast for 1995		Forecast for 2000	
	OEM	Supplier	OEM	Supplier
Throttle body	25%	30%	5%	15%
Port (multi-point)	75	70	95	85

TRENDS FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table, multi-point fuel injection (MPI) appears destined to become the predominant fuel system by the end of this decade. Although there was an indication in all previous Delphi surveys that carburetion would be present in NAPPVs at least though 1995, present Delphi forecasts clearly indicate that in the next century it will be a technology confined to truck applications and the aftermarket.

Fuel-Management Systems	1984 Delphi III	1987 Delphi IV	1989 Delphi V		1991 Delphi VI	
	1992	1995	1995	2000	1995	2000
Throttle body	50%	40%	35%	25%	30%	10%
Port (multi-point)	30	58	60	75	70	90
Carburetion	20	2	5	0	0	0

STRATEGIC CONSIDERATIONS

It is readily apparent that the demise of the carburetor is a matter of fact. The only question remaining is the degree of application of the multi-point versus the single point or throttle-body fuel injection. Generally, we have witnessed a significant shift in expectations toward the multi-point design, perhaps dictated by better performance, tighter emissions regulations, and the prospects for tougher CAFE standards, even though the cost is greater. In addition, some of the economies of scale with the multi-point system have begun to achieve modest reductions in cost. Furthermore, there is some evidence that a hybrid type of system might emerge, which may provide some of the cost advantages of the single-point design with the control capability of the multi-point system.

The only future life for the carburetor will probably be in truck applications and the aftermarket, and these applications will continue to fade as older engine designs and vehicles are ultimately eliminated. We will probably begin to see increasingly more sophisticated multi-point designs, such as the sequential system and those that ultimately will provide individual cylinder control of mixture ratio.

TECH-58. What percentage of North American-produced spark-ignited engines for passenger cars will be either turbocharged or supercharged in model years 1995 and 2000?

Forced Induction Systems	Median Response	Interquartile Range
	2000	2000
Turbocharged	5%	4/5%
Supercharged	2	1/5

SELECTED EDITED COMMENTS

- Alcohol fuel, and its higher anti-knock quality, is particularly "friendly" to superchargers.
- The application depends on two-cycle application.
- Emission standards will be the end of turbochargers.
- Need for displacement reduction (fuel economy) and package efficiency makes supercharging attractive, especially for low- to mid-range torque enhancement.
- Reliability and maintenance issues will limit use of these devices.
- Supercharging has been around a long time. Without breakthrough technology it will not make it.
- Tough CAFE legislation may trigger new interest in turbocharging for high performance models.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturers and supplier panelists are in agreement on their 1995 and 2000 forecasts for the percentage of spark-ignited engines for NAP light-duty vehicles that will be either turbocharged or supercharged.

TRENDS FROM PREVIOUS DELPHI SURVEYS

In 1979, Delphi I panelists forecast that in 1990, 25% of spark-ignited engines in U.S.-produced light-duty vehicles would be turbocharged. In 1981 Delphi II panelists forecast 10% turbocharging in 1990. This 10% forecast for 1990 held steady through Delphi III and Delphi IV. It is estimated that in the 1990 model year, only 3.3% of NAP cars were turbocharged.

Similarly, previous Delphi forecasts for supercharging also indicated a downward trend. From a Delphi II high of 5% in the 1990 model year, projections for supercharging in 1990 dropped to 2% in Delphi III and 1% in Delphi VI. It is estimated that 0.02% of NAPPVs were supercharged in the 1990 model year.

The following table illustrates the forecast trend for supercharged and turbocharged NAPPVs for the years 1995 and 2000.

Forced Induction Systems	Forecast for 1995		Forecast for 2000	
	1989 Delphi V	1991 Delphi VI	1989 Delphi V	2000 Delphi VI
Turbocharged	5%	4%	5%	5%
Supercharged	2	1	3	2

STRATEGIC CONSIDERATIONS

Expectations of our Delphi panelists for both supercharged and turbocharged engines have remained modest over the years. This trend continues with the present forecast. Clearly, there is a role for both devices in low- or medium-volume applications, such as specialized variations of high-volume vehicles and elite or image vehicles within a given family of products. The cost and benefit aspects of both technologies must be compared against the multi-valve engine designs, which can achieve similar specific power levels. Of course capital investment and product development timing factors are important to this decision. It is noted in the comments that new CAFE regulations could perhaps lead to a resurgence of interest in order to provide greater power potential for small, efficient engines. All things considered, it is generally less expensive to boost power by increasing displacement rather than by utilizing external boost or multi-valve designs.

TECH-59. What percentage of North American-produced passenger cars with spark-ignited engines will incorporate the following ignition systems in 1995 and 2000?

Ignition Systems	Median Response		Interquartile Range	
	1995	2000	1995	2000
Distributorless ignition systems	50%	75%	50/50%	70/80%
Individual cylinder control of ignition	40	60	30/45	50/70
Knock/adaptive control	40	65	30/50	60/80
Coil-on-plug designs	5	10	5/5	10/15

SELECTED EDITED COMMENTS

- Ignition control will be used to control emissions as EPA limits get tighter.
- Individual knock control has been badly delayed by excessive patent royalty demands.
- Performance benefit's diminishing returns do not justify higher cost and complexity.
- Use of these technologies will increase as patent protection expires. These technologies are interrelated.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in close agreement in their forecasts for advanced ignition systems. With two minor exceptions, the forecasts are identical with very close interquartile ranges, indicating a high degree of consensus. The two minor exceptions are 1) individual cylinder control for which the OEM panelists forecast 40% for 1995, and the supplier panelists forecast 30% and 2) knock/adaptive control in the year 2000, for which the OEM panelists forecast 70%, and the suppliers 60%, with both groups exhibiting very close IQRs.

TRENDS FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table, the present Delphi panelists demonstrate an increased enthusiasm for the incorporation of knock/adaptive control and distributorless ignition systems by the 1995 model year. The year 2000 forecasts from both Delphi V and Delphi VI are consistent with the trend toward increased application of these ignition features. However, in comparison with Delphi V, the present Delphi panelists in their forecasts for the year 2000 expect a smaller percentage of individual cylinder control of ignition and coil-on-plug designs than did the Delphi V panelists.

Ignition Systems	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Knock/adaptive control	55%	30%	40%	60%	65%
Distributorless ignition systems	50	40	50	75	75
Individual cylinder control of ignition	20	40	40	75	60
Closed-loop timing	15*	10	**	25	**
Coil-on-plug designs	*	5	5	15	10

* In Delphi IV coil-on-plug and closed-loop timing were considered a single category.

** Not surveyed in Delphi VI.

STRATEGIC CONSIDERATIONS

Continuing change is forecast in ignition systems. The present forecast is generally consistent with Delphi V; but in the case of knock/adaptive control and distributorless ignition systems, there is increased optimism. However, there are modestly decreased expectations for individual cylinder control of the ignition process for the year 2000. It appears likely that more restrictive future emissions standards and the possibility of tougher CAFE requirements could drive this technology rather strongly in the years ahead. Ignition systems have really been changed dramatically over the last 10-15 years, and, as this survey suggests, the high rate of change will continue. The interquartile results are reasonably tight indicating that there is a relatively high degree of consensus with regard to all of these technologies, which, by the way, are highly interrelated.

There is considerable debate as to how much the use of these ignition technologies will improve combustion, and what the real cost benefits are. Still, there appears to be significant industry interest. Also, it should be noted that the comments suggest that there appear to be some significant patent issues with these technologies, which could be impeding broader application. In any event, the technology related to engine ignition systems and control of timing is hardly stable and is expected to become substantially more sophisticated in the years ahead. This will create new engine electrical system supply opportunities, but also may mean obsolescence of present componentry and manufacturing capacity.

Finally, we might observe that there appear to be some interesting ignition systems being evaluated, such as plasma devices, rail systems, and others that may continue to keep this field from stabilizing for some time to come (see TECH-63).

TECH-60. What percentage of North American-produced passenger car engines with poppet valves will incorporate the following number of valves per cylinder in 1995 and 2000?

Engine with:	Median Response		Interquartile Range	
	1995	2000	1995	2000
2-valves per cylinder	76%	65%	75/80%	50/65%
3-valves per cylinder	5	5	3/5	4/5
4-valves per cylinder	14	25	10/20	21/32
5-valves per cylinder	5	5	1/10	2/15
TOTAL	100%	100%		

SELECTED EDITED COMMENTS

- Five-valves will be much less than 1%.
- Any more than four-valves is a gimmick.
- I have trouble believing five-valves per cylinder is a practical solution.
- More than two-valves will be the price of entry in smaller displacement engines.
- Some two-stroke engines will have no valves.

DISCUSSION

It is our opinion that although the interquartile range for five-valve engines is very broad, the forecast should be presented as an indication of possible five-valve utilization.

MANUFACTURER/SUPPLIER COMPARISON

There is no significant difference between the OEM and supplier panelists regarding their forecasts for the percentage of penetration of multi-valved engines in NAPPVs.

TRENDS FROM PREVIOUS DELPHI SURVEYS

The trends table indicates that there appears to be an inhibition on the part of the Traditional American Manufacturers (TAMs) to dramatically increase the utilization of multi-valve engines. Instead, there is an inclination of the part of the TAMs to reduce the amount of so-called high-tech powertrain technology and instead to apply this effort and investment to lower-tech, but higher-performance engines. Although multi-valved engines are forecast to increase by the end of the decade, the perceived need for multi-valved engines as a competitive factor for NAPPVs is greatly debated.

Engines with:	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
2-valves per cylinder	70%	80%	76%	60%	65%
3-valves per cylinder	20	5	5	10	5
4-valves per cylinder	10	15	14	30	25
5-valves per cylinder	N.A.	N.A.	5	N.A.	5
TOTAL	100%	100%	100%	100%	100%

N.A. = not asked

STRATEGIC CONSIDERATIONS

The number of valves per cylinder has been a topic of considerable discussion during the past few years. Generally, a high-tech engine is viewed to be one with three- or four-valve cylinder heads and overhead cams, whereas a lower-tech

design generally consists of two valves with push rod actuation. As is evident from previous Delphi surveys, enthusiasm for multi-valve engines in North American vehicles was very high several years ago, but has faded (as shown by reduced expectations for the remainder of the decade). Initial enthusiasm has been reduced, in part due to improved understanding of the merits and demerits of this configuration. Initial comparisons were based on generally foreign-produced, high-tech, high-precision engines, which were compared with lower-tech but also relatively low-precision American designs. However, in recent years even the low-tech designs have been considerably improved with regard to manufacturing precision, resulting in substantial increases in power and reduced friction and fuel consumption while still maintaining a relatively low cost. The multiple problems of greater system complexity, higher revolutions per minute required to develop a given power level, higher cost, and greater upper engine bulk appear to be dampening enthusiasm for high-tech designs even though the multi-valve engine has considerably higher specific power, better combustion chamber shape, and other advantages. It is also unclear as to what impact tighter emissions and possible, future CAFE requirements will have.

It also seems clear that the market will probably be a strong determinant with regard to future designs. Where customers are interested in the technology by which power is developed, the multi-valve engine is likely to be favored. However, where function rather than technology is the major criteria, the lower cost and other advantages of the "old-fashioned" design suggest that the old may not be ready to die. The uncertainties with regard to two-, three- or four-valves and the possible role of the two-cycle engine create a particularly high level of uncertainty for valvetrain component producers. We do not see this uncertainty diminishing for many years to come.

TECH-61. What percentage of North American-produced passenger car engines will utilize the following valvetrain configuration in 1995 and 2000?

Valvetrain Configurations	Median Response		Interquartile Range	
	1995	2000	1995	2000
Push rod	45%	30%	40/50%	25/30%
Single overhead camshaft	45	50	40/45	44/50
Dual overhead camshaft	10	18	10/15	15/25
No camshaft (e.g., electro-magnetic actuation)	0	2	0/0	0/5
TOTAL	100%	100%		

SELECTED EDITED COMMENTS

- By the year 2000 we will see 2-3% of engines other than cam-driven.
- Overhead cams will become the standard configuration as the industry moves to four valves per cylinder.
- Push rods will make a resurgence for two reasons: cost and better packaging.
- Some engines will have no cams.
- Wider usage of single/dual overhead camshafts will track usage of in-line (versus V-block) engines.

MANUFACTURER/SUPPLIER COMPARISON

As illustrated in the following table, the manufacturer and supplier panelists are in general agreement for valvetrain configuration in the years indicated.

Valvetrain Configurations	Manufacturer		Supplier	
	1995	2000	1995	2000
Push rod	47%	29%	45%	30%
Single overhead camshaft	42	49	45	49
Dual overhead camshaft	11	20	10	20
No camshaft (e.g., electro-magnetic actuation)	0	2	0	1
TOTAL	100%	100%	100%	100%

TRENDS FROM PREVIOUS DELPHI SURVEYS

The trends table for valvetrain configurations is a representation of the differing opinions on the part of the TAMs regarding the utilization of single overhead camshafts (SOHC) and dual overhead camshafts (DOHC). An assumption can be derived that commercial application of SOHC or DOHC is not viewed by the average American car buyer as having a perceivable cost benefit, or by the OEMs as having a competitive advantage in the standard NAPPV.

Valvetrain Configurations	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Push rod	30%	60%	45%	60%	30%
Single overhead camshaft	50	30	45	30	50
Dual overhead camshaft	20	10	10	10	18
No camshaft (e.g., electro-magnetic actuation)	N.A.	N.A.	0	N.A.	2
TOTAL	100%	100%	100%	100%	100%

STRATEGIC CONSIDERATIONS

The forecasts for camshaft configuration (push rod versus single or double overhead designs) have changed rather significantly over the past few Delphi surveys. The push rod configuration surged in expectations from Delphi IV to Delphi V, but faded in Delphi VI. The single overhead cam is forecast to increase rather significantly because of its relative simplicity and lower cost compared with the double overhead cam design; it is expected to be used in 50% of the engines produced in North America by the year 2000. Still, push rod designs are expected in 30% of the engines. The lower cost of this design plus the fact that some present day new and very good push rod engines will still be in the marketplace as price leaders ensure that the simple arrangement is not likely to disappear. However, most engines with fundamentally new designs probably will use an overhead arrangement with the single cam considerably used more than the double overhead cam.

Also, we have observed the growing interest, although minor, in a "no camshaft" design, which would perhaps use an electro-magnetic valve actuation system. This type of system would appear to possess some inherent advantages in terms of dynamic or active timing and lift control, which could be a major asset for both improving fuel economy and emissions. This is a challenging problem because the high forces required to maintain effective sealing present major problems for electro-magnetic devices. Recognizing this, we still believe this is an area where there is considerable room for creativity in the years ahead. Many of the comments with regard to high-tech, high-precision engines and low-tech, high-precision engines are germane to this discussion. Ultimately, it seems clear that camshaft configuration decisions will be made on the basis of economics and overall performance requirements. New emissions standards, the prospect of tougher CAFE requirements, and growing economic concerns ensure a high level of uncertainty for some time.

TECH-62. What percentage of passenger car engines produced in North America in 1995 and 2000 will incorporate aluminum cylinder heads and/or blocks?

NAPPV Engines with:	Median Response		Interquartile Range	
	1995	2000	1995	2000
Aluminum heads	40%	60%	40/50%	50/80%
Aluminum blocks	7	20	5/10	10/40

SELECTED EDITED COMMENTS

- The big switch to aluminum is on to gain mass reduction.
- I foresee major increase in aluminum use (with iron liners).
- This is a must-do to lower mass.
- You will see some magnesium in the year 2000.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in very close agreement on the production of aluminum heads in both 1995 and 2000. They are also in close agreement regarding aluminum blocks in 1995. However, forecasts for aluminum blocks in the year 2000 indicate a significant disagreement with the OEM panelists projecting the incorporation of aluminum blocks in 25% of NAPPVs, double that of the suppliers forecast of only 12%.

COMPARISON OF FORECASTS: MAT-29

As indicated in the following table, the Materials panelists forecast a relatively higher percentage of aluminum heads in 1995 and 2000, and blocks in 1995 than the Technology panelists. The forecasts of both panels for aluminum blocks in the year 2000 are equal at 20%. Both panels also presented tight IQRs in their forecasts of aluminum heads for 1995. However, both panels presented high IQRs for aluminum heads in 1995 and aluminum blocks in 1995 and 2000. This indicates a considerable degree of uncertainty within the panels regarding the use of aluminum in NAPPV engine blocks.

NAPPV Engines with:	Technology panel		Materials panel	
	1995	2000	1995	2000
Aluminum heads	40%	60%	50%	70%
Aluminum blocks	7	*	10	*

* No significant difference

TREND FROM PREVIOUS DELPHI SURVEYS

As indicated in the following table, since Delphi IV (1987) there has been a progressively decreasing 1995 forecast for aluminum heads. The same statement can be generally allied to the forecasts for aluminum blocks.

These downward forecast trends appear to reverse by the year 2000; the forecasts for that year indicate a dramatic increase in both aluminum blocks and heads. Although there is a somewhat reduced forecast for aluminum heads presented by Delphi VI panelists, the trend is obviously toward increased aluminum utilization in engines.

Light-Duty Engines	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Aluminum heads	60%	50%	40%	70%	60%
Aluminum blocks	15	6	7	12	20

STRATEGIC CONSIDERATIONS

The trend to aluminum in engine cylinder heads, and to a lesser extent, cylinders blocks is continuing and is generally consistent with the forecast of recent Delphi surveys. The forecast for aluminum cylinder heads for 1995 and 2000 is slightly less than Delphi V, whereas the forecast for aluminum blocks is greater. The quartile range for the year 2000 is reasonably broad indicating a modest level of uncertainty. As the industry moves forward with its aggressive plans to redesign a major fraction of engines produced in North America during this decade, aluminum figures prominently as an engine material. If, as many suspect, there is a significant increase in CAFE standards, it seems likely that the trend to aluminum could accelerate as a means to achieve mass reduction in future vehicles. We believe the use of aluminum in engines is an efficient way to reduce mass at a relatively low cost compared to other areas of the vehicle.

A comment made by one panelist raises an interesting point. With regard to the possible role of magnesium in major engine components in the years ahead, this comment should not be discounted in light of the important progress made in recent years with magnesium. It should also be remembered that cast iron is hardly a stationary target for lightweight metals. Considerable improvements continue to be made leading to surprising levels of mass reduction. Some new technologies give promise of reducing the mass difference to reasonably low values. However, these technologies must be demonstrated in high-volume production to be considered a real threat.

These data are generally consistent with other areas of this report, suggesting that powertrain trends will be dynamic, and in may respects, unpredictable in the years ahead. Clearly, both fuel economy and emission standards will have a significant impact on future engine materials.

The value of a pound of weight saved is expected to increase rather markedly, (as evidenced in TECH-21) and should reinforce expectations for aluminum. On the other hand, cast iron presents important advantages in terms of engine noise, tolerance to overheating, low cost, and other considerations that have led to the prominent role that cast iron still plays in today's engines.

TECH-63. What percentage of North American-produced passenger car engines will incorporate the following technical features in 1995 and 2000?

Technical Features	Median Response		Interquartile Range	
	1995	2000	1995	2000
Fast-burn combustion chamber	70%	80%	65/75%	75/90%
Roller lifters	50	70	40/60	50/80
Balance shaft (% of 4-cylinder engines)	25	30	20/25	20/50
Balance shaft (% of 6-cylinder engines)	20	30	15/25	20/35
Powdered metal camshaft and gears	10	20	10/15	10/30
Hollow camshaft	10	15	5/15	10/30
Lean-burn technology (general)	5	8	5/10	5/20
Twin spark plugs per cylinder	2	2	1/3	1/5
Plasma (or other advanced) ignition	1	1	0/1	0/4
Axial-stratified charge	1	1	0/1	0/2

Other single responses include: Ceramic wafer tappets for low friction and wear (1995 = 10%, 2000 = 20%); powdered metal components (1995 = 15%, 2000 = 70%); and direct combustion sensing (1995 = 0%, 2000 = 10%).

SELECTED EDITED COMMENTS

- Lean-burn technology in 2000 will be 0% unless NO_x catalyst development is successful.
- Powdered metal technology will see increasing use in engines. Powdered metals use on camshafts and gears is not indicative of total use.

MANUFACTURER/SUPPLIER COMPARISON

Technical Features	Forecast for 1995		Forecast for 2000	
	OEM	Supplier	OEM	Supplier
Fast-burn combustion chamber	70%	68%	85%	75%
Roller lifters	50	45	75	60
Balance shaft (% of 4-cylinder engines)	20	25	30	30
Balance shaft (% of 6-cylinder engines)	20	25	25	30
Powdered metal camshaft and gears	10	15	20	20
Hollow camshaft	10	10	20	14
Lean-burn technology (general)	5	8	7	12
Twin spark plugs per cylinder	2	2	2	3
Axial-stratified charge	1	1	1	1
Plasma (or other advanced) ignition	1	1	1	2

TRENDS FROM PREVIOUS DELPHI SURVEYS

The following table presents a comparison of Delphi IV, V, and VI engine technical feature forecasts.

Technical Features	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Fast-burn combustion chamber	75%	65%	70%	80%	80%
Roller lifters	50	40	50	60	70
Balance shaft (% of 4-cylinder engines)	25	20	25	40	30
Lean-burn technology (general)	20	5	5	15	8
Powdered metal camshaft and gears	20	10	10	20	20
Hollow camshaft	15	10	10	20	15
Balance shaft (% of 6-cylinder engines)	10	20	20	20	30
Variable valve timing	10	5	2*	10	10*
Twin spark plugs per cylinder	5	2	2	4	2
Axial-stratified charge	2	1	1	2	1
Plasma (or other advanced) ignition	2	1	1	2	1

* See TECH-68

STRATEGIC CONSIDERATIONS

The Technology panelists forecast a host of significant engine technologies from fast-burn chambers and roller lifters, to the possible application of axial-stratified charged combustion and plasma ignition. Generally, the results were consistent with Delphi V. The forecast differences in most cases are probably not significant. Fast-burn combustion chambers are viewed as likely to become a standard feature of modern engines, and the continued high expectations for roller valve lifters is also evident.

There is somewhat reduced expectations for balance shafts in four-cylinder engines, perhaps because of the improvement of microprecision of engines, which reduces to some extent the need for dealing with engine vibration forces. On the other hand, expectations have expanded for the use of balance shafts in six-cylinder engines. This suggests that six-cylinder engines may increasingly be viewed as upper-level vehicle engines; customers will be more sensitive to vibration and modestly less impacted by the higher cost. In any event, for both four- and six-cylinder engines, customers expect increasing engine smoothness.

Expectations for lean-burn technology have lessened, which is surprising considering the recent announcements by some of the Japanese manufacturers of progress in lean-burn engines. On the other hand, when confronted with the reality of very rigorous future emissions standards and the difficulty of applying lean-burn technology to large engine displacements, the forecast may indicate the reality of this technology with regard to meeting future emissions standards even with the potential fuel-economy benefits.

Powdered metal camshaft lobes continue to receive modest support from panelists, as does the application of hollow camshafts. We generally believe that the engine camshaft is an area with significant potential for innovation. With the high level of engine redesign forecast, a significant change might be realized in this component during the next few years. The no-camshaft engine concept is raised by the panelists in another question. This would truly provide some important benefits in terms of overall simplicity of the valvetrain, and potentially the ability to achieve variable timing and lift quite efficiently.

The remaining technologies discussed in this question, twin spark plugs per cylinder, axial-stratified charge combustion, and plasma ignition received only token support, in fact, less than received in Delphi V. This suggests that some degree of realism has perhaps crept into the technical community as they have gained more experience with some of these technologies.

The prospects for tough fuel economy standards and lower emissions will continue to encourage developments on a worldwide basis of a variety of engine technologies. However, at the most fundamental level, there is probably no magical solution to current challenges, but still room for considerable innovation. Needless to say, this is an area that requires careful watching in the years ahead. The potential for surprises is high and all engine components could be impacted.

TECH-64. What percentage of North American-produced passenger car engines will incorporate these polymer-based components by 1995 and 2000?

Polymer-Based Engine Components	Median Response		Interquartile Range	
	1995	2000	1995	2000
Valve covers	10%	30%	10/15%	25/40%
Intake manifold	5	20	5/5	10/25
Oil pan	5	15	2/5	10/20
Piston skirts	0	2	0/1	0/5
Rocker arms	0	1	0/1	0/5
Connecting rods	0	1	0/0	0/2

Other single responses include: aluminum matrix (1995 = 10%, 2000 = 20%); water pump (1995 = 1%, 2000 = 4%); camshaft and belt pulleys (1995 = 15%, 2000 = 40%); and fuel rails (1995 = 5%, 2000 = 30%).

SELECTED EDITED COMMENTS

- This area offers engine components a great opportunity for polymer technology.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TRENDS FROM PREVIOUS DELPHI SURVEYS

The following table represents the percentage of polymer-based engine components forecast by previous Delphi panelists for the years 1995 and 2000.

Polymer-Based Engine Components	Forecast for 1995*		Forecast for 2000	
	1987 Delphi IV	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Intake manifold	10%	5%	15%	20%
Oil pan	10	5	20	15
Valve covers	10	10	30	30
Connecting rods	0	0	0	1
Piston skirts	0	0	0	2
Rocker arms	0	0	0	1

* 1995 was not surveyed in Delphi V.

STRATEGIC CONSIDERATIONS

Various polymer-based materials are receiving significant consideration for some engine components, particularly the intake manifold, oil pan, and valve covers. Today there are some notable applications already in production. The view of the future is quite optimistic in several instances, although the relatively broad interquartile range for the year 2000 suggests that there is substantial uncertainty. Generally, the results are consistent with the forecasts in Delphi V. There has been, however, a modest downgrading of expectations for 1995 for intake manifolds and oil pans, perhaps because 1995 is almost at hand and designs are committed. Consequently, the forecast for 1995 is perhaps not a forecast but the measure of the reality of the current design programs. In the year 2000 a very small role is forecast for primary engine components and the results are consistent with those of Delphi V. Limited enthusiasm was expressed for plastic-based composite connecting rods, piston skirts, and rocker arms. As with many areas of new or advanced technology, trends must be watched closely due to potential surprises associated with the new materials and production technology. It must be remembered that current technology is hardly stationary, and we expect any new material to confront a tough moving target for new plastic-based components.

TECH-65. What percentage of spark-ignited engines in North American-produced passenger cars will use the following ceramic engine components in 1995 and 2000?

Spark-Ignited Engines Ceramic Components	Median Response		Interquartile Range	
	1995	2000	1995	2000
Turbocharger turbine/rotor (based on % of engines equipped with turbochargers)	10%	20%	2/15%	15/40%
Seals	2	5	1/2	4/5
Valvetrain components (includes valves, inserts, guide seats, tappets, camshaft, etc.)	2	10	1/2	5/10
Exhaust manifold/port liner	1	5	0/1	2/5
Piston crown	0	2	0/0	1/2
Piston rings, coatings	0	5	0/0	1/5

Other single responses include: piston pin (1995 = 0%, 2000 = 10%); and bearings (1995 = 1%, 2000 = 3%).

SELECTED EDITED COMMENTS

- Ceramic bearings have a number of advantages and could find applications in two-cycle engines, etc.
- Ceramics are of more interest in diesels.
- Ceramics have a long way to go before they are ready for these automotive components. Turbocharger bearings are a good application.
- Port liners are not proving to be practical.
- Ceramics will be slow to implement into U.S. designs.
- There will be advances in piston ring coating materials but they will not be ceramic.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and supplier panelists are in agreement regarding the use of ceramic engine materials in 1995. For the year 2000, the supplier panelists have a modestly higher expectation for piston ring coatings (OEM = 2%; suppliers = 5%).

Ceramic Engine Components	Percent Usage in Spark-Ignited Engines			
	Forecast for 1995		Forecast for 2000	
	OEM	Supplier	OEM	Supplier
Turbocharger turbine/rotor	10%	10%	20%	20%
Seals	2	2	5	5
Valvetrain components (includes valves, inserts, guide seats, tappets, camshaft, etc.)	2	2	10	10
Exhaust manifold/port liner	0	1	5	2
Piston crown	0	0	2	2
Piston rings, coatings	0	0	2	5

COMPARISON OF FORECAST: MAT-28

The Material and Technology panelists are in close agreement on the forecast for 1995 and 2000 valvetrain ceramic usage. The Material panelists are more optimistic regarding ceramic exhaust manifold applications and more pessimistic regarding turbocharger usage. The following table presents these differences. It appears that the Technology panelists believe processing, durability, and reliability problems can be overcome for turbocharging applications, however, their wide interquartile range suggests great uncertainty.

Ceramic Engine Components	Percent Usage in Spark-Ignited Engines			
	Technology Panel		Materials Panel	
	1995	2000	1995	2000
Turbocharger turbine/rotor	10%	20%	5%	15%
Valvetrain components (includes valves, inserts, guide seats, tappets, camshaft, etc.)	2	10	3	10
Exhaust manifold/port liner	1	5	3	8

TRENDS FROM PREVIOUS DELPHI SURVEYS

As indicated in the trends table, there is an increased expectation for the use of ceramic materials in turbo-charger turbine and rotor. The forecast for the utilization of ceramics in the other engine components are either static or diminished.

Ceramic Engine Components	Percent Usage in Spark-Ignited Engines			
	Forecast for 1995		Forecast for 2000	
	Delphi V	Delphi VI	Delphi V	Delphi VI
Turbocharger turbine/rotor	5%	10%	15%	20%
Exhaust manifold/port liner	3	1	10	5
Piston crown	2	0	8	2
Seals	2	2	10	5
Valvetrain components (includes valves, inserts, guide seats, tappets, camshaft, etc.)	2	2	10	10
Piston, rings, coating	0	0	0	5

STRATEGIC CONSIDERATIONS

Ceramics continue to be an elusive material as applied to engines. About ten years ago, amid much fanfare, the powertrain expectations for the ceramic applications were relatively high. The present forecast for ceramic components is rather modest for the next eight to ten years, but still suggests that ceramics will be a material with reasonably significant applications in the powertrain. Of course, it must be recognized that if manufacturing and cost problems are resolved, interest in ceramics could escalate rather dramatically. For example, it already seems clear that where turbochargers are used, ceramic "hotwheels" are very attractive and will probably become the dominant technology over the long term. The virtues of the ceramics including high temperature performance, thermal insulation and wear resistance can be of significant value in some components. However, it should be noted that in-cylinder applications with spark-ignition engines can cause increases in gas temperatures, and cause problems with engine octane requirement. Furthermore, higher temperatures could exacerbate problems of NO_x emissions. In contrast, the diesel engine can use higher cylinder temperatures to its advantage with respect to emissions and fuel octane requirements.

It is clear that manufacturing considerations are still a key barrier to the application of ceramics, as are durability problems associated with microfractures in the structure that could lead to catastrophic failure in such areas as valves or

pistons. We continue to see no real enthusiasm for a so called ceramic-intensive engine. Rather, ceramics will be used, at best, on a part-by-part basis in future engines.

Finally, it must be noted that any problems with a material's reliability or durability that would compromise engine quality in any way must be dealt with appropriately. Satisfying today's quality-conscious customer requires it.

TECH-66. What percentage of gasoline-fueled NAPPVs will have fuel tanks made from either steel or plastic/polymer or aluminum in the years indicated?

Gas tank material	Median Response		Interquartile Range	
	1995	2000	1995	2000
Steel	80%	65%	70/90%	50/70%
Plastic/polymer	20	33	10/25	20/50
Aluminum	0	2	0/2	0/10

SELECTED EDITED COMMENTS

- It depends on evaporative emissions and alternate-fuels developments and requirements.
- Flexible-fuel requirements and clean-air regulations on running losses (permeation) and polymer compatibility with various fuels will keep plastic/polymer tanks out. In fact, they will lose market share for a while.
- Plastic gas tanks are an emerging technology.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

The fuel tank became an important area of material competition during the last few years. Coated steel is still the dominant material today, although significant inroads are being made by plastics. Aluminum is also beginning to appear as a candidate material for the latter part of this decade. There is a rather broad quartile range for both plastic and aluminum, suggesting that the uncertainty level is high for both materials.

Advantages for plastic have been reported to include the ability to occupy more complex volumetric shapes and component integration leading to lower cost. The panelists' comments on both emissions standards and alternate-fuel developments should be considered seriously. Both factors are likely to have an impact on fuel tank material selection. For example, methanol attacks the coatings used on today's steel fuel tanks and may be a serious problem for many plastic materials. This is likely to remain a somewhat fluid topic for a number of years and an area of intense material competition. The general trend appears to be heading in the direction of polymers. However, based on experience in other areas, the traditional material suppliers, when challenged, can provide competitive responses to the new candidates.

It would appear that product liability concerns regarding plastics that were initially raised, have been set aside as a result of the generally positive experience with present designs. As with any area of intense materials competition, developments must be monitored closely.

TECH-67. **There are major concerns regarding the use of alcohol-based fuels in NAPPVs and automotive material selection decisions, particularly with respect to fuel tanks. What percentage of alcohol-fueled NAPPVs will use the following fuel tank materials by MY 2000?**

Fuel Tank Material for Alcohol-Fueled Vehicles by 2000	Median Response	Interquartile Range
Stainless steel	30%	10/85%
Coated low carbon steels	20	9/40
Polymer-based materials	10	5/60

Other single responses include composites (5%).

SELECTED EDITED COMMENTS

- Alcohol-fueled vehicles will only be a small minority of the cars built in North America.
- Composites consist of inert coated or layered polymer materials.
- No reliable coating appears to be coming in the near future.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

With increasing expectations for the use of alcohol in fuels, either as a pure fuel or in combination with gasoline, a key materials issue is fuel tank material. As noted in the discussion of the prior question, many materials are attacked by alcohols, and this problem must be resolved before alcohol becomes a reasonable alternative fuel. The panelists generally viewed stainless steel as the preferred material, compared with both low carbon steels and polymer-based materials. However, we view this as quite undesirable because of the high cost of stainless steel relative to the basic cost of the material and fabrication challenges.

Alcohol is not likely to become a dominant fuel over the next ten-year period, but it will likely experience significant use in some areas. For example, General Motors has recently announced production of a modest number of vehicles capable of using a broad range of alcohol and gasoline blends. We believe that material developments in both plastics and lower-price metals may yield positive results. However, as one panelist noted, reliable coatings do not appear to be coming in the near future. This casts a cloud over the use of lower-cost materials. With regulatory requirements and the durability expectations of today's customer, the use of alcohol or other fuels is not a trivial issue. Finally, we must question how much faith we can place in short-term, accelerated materials testing when vehicles are expected to perform over a number of years.

TECH-68. What percentage of engines produced in North America by traditional domestic manufacturers will employ the following valvetrain technologies in the years 1995, 2000, 2005?

Valvetrain Technologies	Median Response			Interquartile Range		
	1995	2000	2005	1995	2000	2005
Variable timing control	2%	10%	20%	1/5%	5/15%	10/30%
Variable lift control	1	5	10	0/1	2/10	5/20

SELECTED EDITED COMMENTS

- Electronic controllers and actuators have limitations.
- Fuel economy will drive variable lift control for controlling load.
- Most proposed mechanical and electro-mechanical techniques to control valve timing and lift are expensive and have potential reliability problems while having limitations on their effectiveness. Full electronic control of valve lift and timing is needed to make significant improvements in engines.
- Variable lift control is more difficult but offers greater advantage.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in agreement in their forecasts for both valvetrain technologies.

TREND FROM PREVIOUS DELPHI SURVEYS

As is evident in the following table, there has been a decline in the expectations for variable valve timing control for 1995. The Delphi VI forecast for the year 2000, however, is consistent with Delphi V. There is no change in the variable lift control forecasts from Delphi V to Delphi VI for either 1995 or 2000.

Valvetrain Technologies	Light-Duty Engines Employing Valvetrain Technologies				
	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Variable timing control	10%	5%	2%	10%	10%
Variable lift control	N.A.	1	1	5	5

N.A. = not asked.

STRATEGIC CONSIDERATIONS

It has been known for some time that variable valve lift and timing can have a positive impact on the performance of the internal combustion engine, particularly, with regard to fuel economy, driveability, and emission formation. With the prospect of tougher CAFE standards and the demanding requirements of the new Clean Air Act, the incentives for variable timing and/or lift control are greater than ever before. It is clear that the problem is not so much within the control strategy but rather with the complexity of the basic mechanism. There may still be some misunderstanding related to potential benefits but, clearly, variable timing and/or lift would offer some improvement in overall engine performance.

Our panelists suggest that there will be reasonably significant use of variable timing and even some introduction of variable lift mechanisms in the decade ahead, although the latter is undoubtedly a more complicated mechanical problem. We must also observe that the interquartile range is broad, which suggests a high level of uncertainty with regard to both technologies. The problems remain formidable. The spring forces required to maintain valves in their closed position are high, as well as inertia forces, and pose significant challenges for mechanisms. This is particularly true for electro-magnetic actuation, which from a control standpoint would appear to be desirable.

The industry's creative and innovative skills are just now being focused on this area. Product and process innovation is required. Of course, there will undoubtedly be serious concerns with regard to the cost/benefit of these technologies.

Today's systems suggest that the cost of lift and timing control may be rather high. This must be viewed as an important area of added value potential for engine component manufacturers.

TECH-69. What percentage of NAPPVs will have active engine mounts in 1995, 2000, 2005?

Percentage of North American-Produced Vehicles with Active Engine Mounts					
Median Response			Interquartile Range		
1995	2000	2005	1995	2000	2005
2%	5%	10%	1/2%	4/5%	5/15%

SELECTED EDITED COMMENTS

- Balance shafts and individual cylinder combustion control may eliminate need for active engine mounts.
- We do not hear a great cry for this technology.
- Electro-rheological fluids (ER) must be perfected, and that is a long way off.
- ER fluids will make this possible. Other methods can not accomplish the same thing.
- May be possible if ER fluids become practical.
- There is a need to differentiate between active (power input) and rapidly adjusted devices.
- ER fluids will have an impact by 2000.
- I expect variable damping hydromounts.
- It will not be worth it with good engines and passive mounts.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Over the last few years there has been growing industry interest in active- or semi-active engine mounts. As noted in the comments section, one panelists raised the issue of fully active (with power input) versus semi-active, or rapid charge, motor mounts. It was not our intent to differentiate between the technologies, but rather to gain some sense of the overall trends in engine-mount technology. Our data indicates there is modestly growing interest in this type of engine-mounting system, which may have particular value in both four- and six-cylinder engines. Of course, the need for special mounts is diminished when balance shafts are used or engines are made with a high level of precision with low-mass reciprocating components. Still, there is growing interest, in part, because of advances in electronic and materials technology and a desire to provide consumers with a minimum vibration powertrain. Electro-rheological-fluid-based mounts, as well as several other technologies, have been suggested that could achieve high levels of isolation. It seems likely that the cost/benefit tradeoff analysis will influence the decision. For example, if one can achieve 75% isolation for ten dollars, it may not be worth one hundred dollars to achieve 95% isolation. The speed with which new mounting technologies based on advanced electronic componentry are being developed suggests that these devices may become practical and will soon justify the forecast.

TECH-70. What percentage applications for electro-rheological (ER) fluids do you foresee for the following features by 2000?

Systems/Components	Median Response	Interquartile Range
Active suspension components	5%	2/5%
Engine mounts	5	2/5
Shock absorbers	5	1/10
Accessory drive components	2	1/5
Drivetrain applications	1	0/2

SELECTED EDITED COMMENTS

- Many breakthroughs must be made before widespread use of this technology is feasible.
- This assumes a few breakthroughs before this technology becomes commercially feasible.
- It depends on development of much better ER fluids. This should be extended to include other controllable property fluids.
- ER fluids still will not be available to meet requirements.
- The high voltage required is one major problem.
- I question whether electro-rheological fluids are going to make it for anything but low energy/low temperature applications such as engine mounts.
- This will not happen until the temperature problems are solved.
- It is a promising technology, but cost/value uncertainties make percentage forecasts impossible at this point.
- The technology still requires extensive development to become viable in an automotive environment (i.e., temperature, extreme high voltages, and cost/benefit, etc.).
- Temperature limitation and electronics (5 Kv) are drawbacks today.
- It is too early to tell. There could be growth here but mostly we have seen only press releases; not hard engineering.

MANUFACTURER/SUPPLIER COMPARISON

With two minor exceptions, the OEM and supplier panelists are in accord regarding the percentage of application of electro-rheological fluids in various systems/components. The OEM panelists forecast a percentage of application of ER fluids in the year 2000 of 5% for both active suspension components and engine mounts; the supplier panelists forecast 3% for both features in the same year.

TRENDS FROM PREVIOUS DELPHI SURVEYS

Electro-rheological fluids (ER) have been suggested for a number of automotive applications, particularly variable shock/strut damping (active suspension components) and engine mounts. Although many obstacles remain to inhibit commercial application (e.g., temperature variability and electrical requirements), a significant interest is maintained in the utilization of ER fluids. In Delphi V the panelists were asked: "What applications for ER fluids do you foresee by the year 2000?" Their responses are illustrated in the following table. It is of interest to note that the applications receiving the largest percentage of total responses from Delphi V panelists are also the same applications that received relatively higher forecasts for percentage of application in Delphi VI.

Delphi V Forecast for ER Fluids Utilization	
Application for Electro-Rheological (ER) Fluids by the Year 2000	**Percent of Total Responses**
Engine mounts	24%
Drivetrain applications	20
Shock absorbers	18
Active-suspension components	14
Accessory drives and clutches	14
Four-wheel-drive couplings	6
No applications	4

STRATEGIC CONSIDERATION

Electro-rheological fluids continue to stimulate the curiosity of engineers throughout the automotive industry. It is an intriguing technology that seems to be searching for an automotive application. Significant developments have occurred in recent years that appear to be bringing ER fluids closer to reality. Still, formidable problems remain, precluding near-term commercial applications. However, our panelists do envision modest use of ER fluids near the end of the decade. A variety of applications are suggested that seem potentially attractive, and are a good fit with the growing application of electronic controls in automotive vehicles.

We believe that developments will continue with aggressive research by a number of firms, increasing the probability that commercial application will be achieved by the year 2000. Our panelists have modest expectations of limited use by the year 2000 in the various areas surveyed.

Because of the potential impact on a number of key vehicle systems, suppliers of these system components should monitor developments carefully. Generally, good advice would be to obsolete your own products before your competition does it for you. Electro-rheological fluids continue to be a highly intriguing and interesting area and, theoretically, very attractive.

TECH-71. With increasing emphasis on vehicle aerodynamics, tighter underhood packaging, higher engine r.p.m. and load, and other factors, how much will underhood temperatures increase by 1995 and 2000?

Increase in Underhood Temperature in Percentage			
Median Response		Interquartile Range	
2000	2005	1995	2000
5%	10%	0/10%	5/20%

SELECTED EDITED COMMENTS

- Better thermal management must more than offset increased powertrain component heat rejection in some areas.
- Conservation of heat energy for emission controls will offset the described losses.
- Essentially underhood temperature is at the limit. It must go down in future years by approximately 10-20° F.
- Styling will have to maintain front air access for radiator and engine compartment ventilation.
- The use of aluminum and magnesium blocks and heads will cause underhood temperatures to increase significantly.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

A number of years ago, when it became apparent that vehicles were going to be significantly downsized and reconfigured to front-wheel drive, we asked for a quantitative response to this question. In the present Delphi we chose to consider temperature change based on a percentage increase because of the difficultly in defining a particular region in the underhood area that could be considered representative. In an area close to the hot manifold, temperatures might be extraordinarily high, whereas near the intake system they would be substantially lower. As noted by the significant number of comments to this question, there appears to be substantial interest in changes in underhood temperatures and a high degree of uncertainty as how to evaluate it.

In a general sense it seems clear that temperatures will continue to increase due to further restrictions of underhood air flow, tighter packaging to reduce weight, and more restrictive emissions standards, which will probably require externally heated and/or closely coupled catalysts. Furthermore, with the growing role of electronics and nonmetallic materials in the underhood area, high temperature can create significant problems. It is particularly important in this highly uncertain and unpredictable area, to review carefully all of the comments that have been made.

The interquartile range of the data is rather broad and suggests a high level of uncertainty. Overall, the temperatures are expected to increase by about 10% by the year 2000, which will undoubtedly create significant challenges for vehicle designers. Increases in CAFE and emission standards will probably add to the magnitude of the overall underhood temperature problem. Component suppliers should be duly warned to prepare for a more difficult environment even as the reliability and durability expectations are increased to provide customer satisfaction and to meet 100,000-mile mandated emissions control durability.

TECH-72. Please estimate the mix of transmissions for passenger cars manufactured in North America in 1995 and 2000.

Passenger Car Transmission	Median Response			Interquartile Range	
	Est. 1990 MY*	1995	2000	1995	2000
Manual					
Four speed	1%	1%	1%	0/1%	0/1%
Five speed	12	12	11	10/13	8/15
Six speed	0	0	1	0/1	0/2
TOTAL Manual	13%	13	13		
Automatic					
Three speed	42%	35	23	30/37%	10/30%
Four speed	45	50	57	48/55	49/65
Five speed	0	1	5	0/3	2/10
Continuously Variable (CVT)	0	1	2	0/1	1/5
TOTAL Automatic	87%	87	87		
TOTAL	100%	100%	100%		

* Source: Automotive News

MANUFACTURER/SUPPLIER COMPARISON

The Manufacturer and Supplier panelists are in close general agreement for the transmission mix of NAPPV for manual and automatic transmissions for MY 1995 and manual for MY 2000. There is, however, a significant difference of opinion regarding the breakout of automatic transmissions for the year 2000.

It is of considerable interest to note that the OEM panelists anticipate a much more rapid transition to four-speed and five-speed automatic transmissions than do the supplier panelists. Considering that the OEMs are in the driver's seat in terms of advanced powertrain technology and the production of automatic transmissions, this difference of opinion indicates that there is a need for dialogue and increased cooperation between the two groups.

Automatic Transmissions by MY 2000		
Automatic	OEM	Supplier
Three speed	15%	30%
Four speed	60	52
Five speed	10	3
CVT	2	2
TOTAL	87%	87%

COMPARISON OF FORECAST: MKT-33a

The Marketing panelists' forecasts for the total U.S. domestic market include both import and domestic. With respect to CVTs, the Marketing panelists forecast a penetration rate at least twice that of the Technology panelists. The IQRs for Marketing, although higher than those for Technology, are commensurate with the median forecast. In both cases the CVT IQRs for MY 2000 indicate a considerable degree of uncertainty regarding percent application. It should be taken into consideration that the higher median and IQRs forecast by Marketing probably reflect the addition of import vehicles with CVTs.

Continuously Variable Transmissions	Delphi VI Marketing Panel Forecast			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Passenger cars	2%	4%	1/2%	1/8%
Light trucks	0	1	0/2	0/4

TRENDS FROM PREVIOUS DELPHI SURVEYS

While a dramatic shift is observed in the 1995 forecast for manual transmissions from Delphi IV to Delphi V, as evidenced in the following table, the Delphi V and Delphi VI forecasts for the percentage of manual and automatic transmissions in both 1995 and 2000 are identical. The only significant change in the trend data is the increase in five-speed manual transmission in Delphi VI compared with Delphi V. There is also a modest increase in the forecasts for four-speed and five-speed automatic transmission. Also the trend data indicates that there are no expectations for an increasing utilization of continuously variable transmissions (CVT).

Transmission Mix	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Manual					
Four speed	5%	7.5%	1%	5%	1%
Five speed	25	5.0	12	7	11
Six speed	N.A.	0.5	0	1	1
TOTAL	30%	13%	13%	13%	13%
Automatic					
Three speed	20%	39%	35%	28%	23%
Four speed	48	47	50	54	58
Five speed	N.A.	0	1	2	5
CVT	2	1	1	3	2
TOTAL	70%	87%	87%	87%	87%

N.A. = not asked

STRATEGIC CONSIDERATIONS

To some extent, the transmission mix forecast appears to be stabilizing. Automatic transmissions are expected to remain overwhelmingly dominant with a forecast essentially consistent with Delphi V. There is a modest increase in expectations for five-speed automatic transmissions, continued change from three-speed to four-speed automatics, as well as a general decline in expectations for four-speed manual transmissions in favor of five-speed designs. Continuously variable transmission (CVT) expectations remain low and generally consistent with the past forecast data. Even as various CVT designs have been introduced in the world, they have not generated sufficient enthusiasm to warrant more attention. And clearly there still seem to be problems with application to larger and more highly powered vehicles. It is also interesting to note that the trend to automatic transmissions, while not as strong as suggested by the forecast for North America, is well underway in Japan and Europe as well. Perhaps more and more people are beginning to feel that automatics can still be fun to drive. Today's customers seem to be increasingly concerned about comfort and convenience, which is generally consistent with the basic concept of the automatic transmission. Furthermore, some of the traditional concerns with the automatic, such as poor shift quality and low fuel economy, are much less significant today.

The role of electronics in automatic transmissions, which is addressed in a separate question, is obviously important to the future of automatic transmissions and perhaps in some versions of manual transmissions as well. Furthermore, as the concepts of system engineering becomes more fully developed, we expect to see far more highly integrated transmission and engine combinations, which may have a significant influence on the number of transmission speed ratios. For example, with more effective torque curve management in the engine, it may be possible to actually reduce the number of transmission speeds to achieve a considerable cost saving. This is increasingly important today because the cost of a modern automatic transmission is in the same general area as the cost of an engine.

While the future transmission mix appears reasonably stable, this in no way suggests that transmission technology will be stable. Beyond the growing role of electronics, other significant changes are probable in basic mechanical function and materials. Some interesting new concepts are being reviewed by the industry and could have a major impact on transmission design and the competitive position of the auto companies.

TECH-73. What percentage of North American-produced passenger cars will use the following drivetrain configurations in 1995 and 2000?

Drivetrain Configurations	Median Response			Interquartile Range	
	Est. 1990 MY*	1995	2000	1995	2000
Front Engine:					
Front drive	86%	88%	87%	85/90%	85/90%
Rear drive	14	11	10	10/14	5/10
Front Engine:					
4-wheel drive	<1	1	3	1/2	1/5
TOTAL	100%	100%	100%		

*Source: Automotive News

SELECTED EDITED COMMENTS

- Assume that four-wheel drive is all-wheel drive.
- Long-term vehicle platforms are in place to support these figures.
- Midengine rear-wheel drive will reach 1%.

MANUFACTURER/SUPPLIER COMPARISON

The OEM and Supplier panelists are in very close agreement on their forecast for drivetrain configuration in 1995 and 2000. The only statistically significant difference of opinion is with regard to four-wheel drive vehicles. In their forecast, the OEM projected 1% for 1995 and 2% for the year 2000; whereas the suppliers forecast 2% for 1995 and 4% for 2000.

COMPARISON OF FORECAST: MKT-33a

The Marketing panelists forecast the penetration rate for four-wheel drive in the total U.S. passenger car market (domestic and import) as 2% in 1995 and 3% in the year 2000. This is not significantly dissimilar from the Technology panelists' forecast for NAPP cars.

TRENDS FROM PREVIOUS DELPHI SURVEYS

It is apparent from the trend data, presented in the following table, that the Delphi VI panelists expect that front-wheel drive will continue to be the dominant drivetrain configuration for NAPP cars through the year 2000. While Delphi V panelists forecast a lesser percentage of front-wheel drive cars for both 1995 and 2000 than did Delphi VI panelists, the dominance of front drive remains. With the demise of the Fiero, the erosion of the midengine rear-drive cars forecast in previous Delphis appeared so complete that the category was not included in the present Delphi. Forecasts for four-wheel drive vehicles by the 1995 MY also demonstrate a progressive decline. However, it is interesting to note that this decline is somewhat reversed in forecast for the year 2000.

Drivetrain Configurations	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Front Engine:					
Front drive	76%	79%	88%	80%	87%
Rear drive	17	17.5	11	14.5	10
Mid-Engine:					
Rear drive	2	0.5	N.A.	0.5	N.A.
Front Engine:					
4-wheel drive	5	3	1	5	3

N.A. = not asked

STRATEGIC CONSIDERATIONS

Front-engine/front-drive is expected to remain the dominant drivetrain technology through the year 2000. In fact, the forecast for front-engine/front-drive has strengthened considerably since Delphi V. This increased trend to front drive is reinforced by the prospects for tighter fuel-economy standards, which place a premium value on the very efficient front-engine/front-drive configuration. The interquartile range for both front engine/rear drive and four-wheel drive is quite broad considering the low value of each median forecast. Consequently there appears to be a high level of uncertainty with both configurations in the future. Four-wheel drive received less support than in Delphi V, which may be due, in part, to advances being made in traction control and to fuel-economy penalties associated with four-wheel drive, penalties which more restrictive CAFE standards would create serious problems for manufactures. This trend may also be associated with what seems to be a general move in the market to more of a value orientation. A number of consumers have certainly selected four-wheel drive not because of real need but rather to have the latest technology or "hot" feature. In this forecast we dropped the midengine category because of the decreasing popularity of this configuration. The fact that there is still strong support for rear-drive suggests that customers will still be interested in high power-to-weight ratio vehicles that can haul large loads and that some people simply feel more comfortable with the traditional rear-drive layout.

The response to this question suggests that there are really no startling surprises on the horizon for drivetrain technology. The basic characteristics of today's drivetrain are likely to continue through the year 2000.

TECH-74. What percentage of North American-produced passenger car automatic transmissions will incorporate electronic control (excluding lock-up torque converter) in 1995, 2000, and 2005?

Automatic Transmissions with Electronic Control					
Median Response			Interquartile Range		
1995	2000	2005	1995	2000	2005
25%	60%	90%	25/40%	50/70%	85/95%

SELECTED EDITED COMMENTS

- Electronic control will be almost 100% by 2005 for automatic transmissions.
- Customer demands for quality in the form of "perfect shifts" will force the use of electronic controls. The ability to help meet fuel economy regulations will also be an incentive.
- This will be paced by "new" transmission and powertrain introduction rate/frequency. Engine and transmission control integrated into a single optimized package will be introduced.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in complete accord regarding their forecast for electronic transmission control. The only minor difference of opinion is in the year 2005 where the OEMs forecast 90% and the suppliers 85%.

TRENDS FROM PREVIOUS DELPHI SURVEYS

In general the Delphi VI 1995 forecast for electronic transmission control is consistent with previous forecasts. There is, however, a significant decrease in the trend data for the percentage of NAPPVs that will incorporate electronic transmission control in the year 2000. It should be noted that the IQR for the Delphi V 2000 forecast of 75% (IQR=60/90%) indicated a considerable degree of uncertainty. Given accelerating competition, the increasing application of electronics, and improvements in shift quality and fuel economy, the 2005 forecast of 90% (IQR=85/95%) points to an overall trend within the industry to move toward an incorporation of electronic transmission control.

Electronic Transmission Control				
Forecast for 1995			Forecast for 2000	
1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
25%	30%	25%	75%	60%

STRATEGIC CONSIDERATIONS

Expectations for application of electronic control to automatic transmissions continue to be very high. This is reinforced by recent trends in the industry. Despite the capital shortages of the industry today, most manufacturers are aggressively pursuing an electronic control strategy for their automatic transmissions. The forecast in Delphi VI, however, is not quite as aggressive as the forecast in Delphi V for electronic control. This suggests, perhaps, some increased concerns with capital requirements and the critical skills necessary to engineer future products.

Another pertinent factor is that the conventional automatic transmission with hydro-mechanical control has been improved rather significantly in recent years, particularly in terms of overall quality, shift quality, durability, and reliability. A further consideration with electronic control is that it aids integration of the engine and transmission controls leading to improved fuel economy and reduced emissions while improving driveability. We think it is safe to assume that any future automatic transmission design will fundamentally incorporate electronic control. It should also be noted that there are some rather significant differences between electronic control approaches and sophistication level between the various manufacturers.

TECH-75. Recently Ford exhibited a "T-Drive" powertrain in which power is delivered from the middle of the engine to the transmission. What percentage of NAPPVs do you forecast will incorporate a type of "T-Drive" technology by the year 2000?

Percent T-Drive by 2000	
Median Response	Interquartile Range
2%	1/5%

SELECTED EDITED COMMENTS

- It is a novelty and does not offer real value on the vast majority of applications.
- Once this change starts it will proceed quickly.
- Powertrain designs (combining engine and transmission into one casting, etc.) will replace separate engine and separate transmission design to improve vehicle packaging. But they will not necessarily be T-drives.
- There will be other systems similar to Ford's, but not exactly.
- Under floor engines, (e.g., Previa) are better for rear-wheel drive, transversal engines and transmission. New in-line 3L GM six-cylinder is better for four-wheel drive.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

During the past year, there has been increasing speculation that an entirely new drivetrain might be developed based on a T-drive principal. Ford exhibited a powertrain of this type at the 1991 North American International Auto Show in which the transmission input is taken off the midpoint of a transversely mounted engine, thus achieving a very attractive package size in contrast to today's front engine, front drive configuration. Panelists' expectations for a T-drive are modest at 2% of production by the year 2000. This indicates that serious consideration is being given to this concept. The quartile range is broad, suggesting a high level of uncertainty. Still responses such as we have observed in Delphi VI, at this earliest stage of development, warrant careful consideration by all powertrain suppliers, as well as others who might be influenced by vehicle package changes associated with this technology. We suspect that there are a variety of different configurations being investigated, as suggested by the panelists' comments. A particularly important comment is that once a change starts toward a T-drive, it could proceed quickly. This could be major news for the industry in the years ahead. Effective execution of a T-drive could provide a significant competitive advantage.

IX. VEHICLE ELECTRONICS/ELECTRICAL SYSTEMS

TECH-76. What fraction of total vehicle dollar value in today's North American-produced passenger car is represented by electronic componentry, and what will it be in 1995 and 2000?

Fraction Total Vehicle Dollar Value Represented by Electronic Componentry							
Median Response				Interquartile Range			
Current Est.	1995	2000	2005	Current Est.	1995	2000	2005
10%	15%	19%	20%	8/11%	10/17%	14/23%	15/25%

SELECTED EDITED COMMENTS

- Expect a significant increase, threefold from now to 1995.
- Cost of electronics will come down fast enough so that the total cost percentage will be almost constant with greatly increased function.
- Electronic content will go up, but unit cost will be reduced to almost balance out.
- If navigation systems and other electronic gadgets become widespread, these numbers will hold. Otherwise, total dollar value will be lower.
- Increasing content will be balanced by more efficient utilization to produce straight line increase in dollar fraction.
- Many mechanical controls will be replaced with electronic actuator/controls.
- The electronic content of cars will continue to grow rapidly, but the push for lower emissions, safer vehicles, better fuel economy will increase the cost and value of mechanical components also.
- Forecast includes entertainment and communication. The micro-electronic cost reduction curve will substantially offset increased fraction.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists are in agreement regarding the dollar value of vehicle electronics/electrical systems.

TREND FROM PREVIOUS DELPHI SURVEYS

It is assumed that economies of scale have reduced, and would continue to reduce the total vehicle cost of automotive electronics. However, current forecasts for the fraction of total dollar value of NAPPV have remained relatively consistent. This forecast may be an indicator of a continuing, increasing application of automotive electronics.

Fraction Total Vehicle Dollar Value Represented by Electronic Componentry				
Forecast for 1995			Forecast for 2000	
1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
20%	15%	15%	20%	19%

STRATEGIC CONSIDERATIONS

Expectations for the role of electronics in future motor vehicles, as measured by the fraction of total vehicle cost represented by electronics, continue to be high. Generally the results of Delphi VI are consistent with previous Delphi surveys, although the spread of opinion is reasonably large, as indicated by the fairly broad quartile range, particularly for the longer range forecasts. However, there is no lessening of increased expectations of electronic applications in future vehicles. Beyond 2000, the fraction of the vehicle cost in electronics should stabilize, in the view of the panel.

The various comments to this question should be carefully noted since several have suggested that the cost of electronics will not change as percentage of total vehicle cost.

We have noted in previous Delphi surveys strong expectations for added electronics application but with decreasing cost per function for a number of reasons, including component integration, reduced cost of individual electronic components, and more effective overall systems engineering for the vehicle. Obviously, the competition will be intense as automotive electronic technology matures. Increasing economic pressures are likely to stimulate an interesting battle between the demand for new electronic-based features and the cost of the overall vehicle. It is also obvious that the vehicle engineer of the future must be as well grounded in basic electronic technology as any of the mechanical sciences that have historically been so much a part of the industry. "Systems thinking" is crucial to ensure the optimum application of electronics in future vehicles.

TECH-77. What percentage of NAPPVs will utilize at least one major multiplexed (MPX) power sub-system by 1995, 2000, and 2005? (Please provide your estimate for current vehicles.)

NAPPV with:	Median Response				Interquartile Range			
	Current Est.	1995	2000	2005	Current Est.	1995	2000	2005
MPX Applications	1%	3%	15%	40%	1/1%	2/5%	10/20%	20/50%

SELECTED EDITED COMMENTS

- Cost will be the main issue.
- It depends on low-cost input/output models, reliability, and savings in wire (and weight benefit). It also depends on reliability and trouble-free performance of early systems.
- Multiplex uses less copper, which saves weight and increases fuel efficiency.
- Multiplexing will yield a substantial benefit in weight and reliability. It is bound to happen.

MANUFACTURER/SUPPLIER COMPARISON

In light of the trend data, the OEM and supplier forecasts for multiplexed subsystems provide an interesting contrast. While the two groups provided identical forecasts of 3% for 1995 and were reasonably close for the year 2000, with an OEM forecast of 10% and a supplier forecast of 15%, they were quite different in their 2005 forecast. In that year, the OEMs projected an MPX utilization percentage of 25% (IQR = 20/50) for NAPPVs while the suppliers forecast a significantly higher MPX utilization percentage of 40% (IQR = 25/50).

TRENDS FROM PREVIOUS DELPHI SURVEYS

As evidenced in the following table, there has been a dramatic declining trend in the forecast use of multiplexing by 1995. Although there is evidence of a substantial increase in the percentage of use by the year 2000, it is still below the forecast of Delphi V. It is significant that the Delphi V forecast of 20% for 2000 exhibited a rather broad IQR of 15/40. While the present Delphi forecast of 15% is less than the previous forecast, it does demonstrate a somewhat tighter IQR of 10/20, demonstrating a higher degree of consensus not evidenced in earlier forecasts. Whether this precipitous decline in the 1995 forecasts is the result of reliability/warranty problems and/or other possible liabilities or cost has not been clearly defined. Nevertheless, the fact that the Delphi VI forecasts for the year 2000 do not reach the 1987 Delphi IV forecasts for MY 1995 should be of particular interest to suppliers of components affected by multiplexing.

NAPPV with:	Forecast for 1995			Forecast for 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
MPX Applications	20%	7%	3%	20%	15%

STRATEGIC CONSIDERATIONS

For a number of years, we have addressed the role of multiplexing in future vehicles in power systems. We have observed some interesting changes compared with the data of Delphi V. Generally, expectations for power multiplexing are significantly less for 1995 and 2000. However, beyond 2000, rapid growth is expected (15% of vehicles in 2000 to 40% of vehicles in 2005). Today, multiplexing seems to be in a holding pattern just ready to take off. Factors that accelerate multiplexing growth include component cost reduction and tight CAFE standards, which would place greater value on weight reduction or technological breakthroughs. The interquartile ranges are quite broad again suggesting that there is a high degree of uncertainty at this time.

As we have noted before, developments must be watched closely. We continue to believe that the incentives remain strong, particularly in areas of the vehicle with tight package constraints, such as the driver's door and steering columns. Another incentive is the continuing quality and reliability problems associated with traditional automotive wiring. With appropriate systems engineering and new thinking, it should be possible to minimize these problems and potentially reduce some of the incentives prompting consideration of multiplexing. We have seen significant evidence of improvements in recent years, which in turn makes the traditional electrical system a fast moving target for competitive technologies.

TECH-78. What percentage of multiplexed systems will utilize a fiber optic control bus technique rather than wire control bus by the year 2000?

Multiplex Systems Utilizing Fiber Optic Bus Percent Application	
Median Response	Interquartile Range
10%	5/10%

SELECTED EDITED COMMENTS

- As vehicle systems become more interactive, they need more and faster data exchanges. Optical buses allow this at an economical price. This may present a significant challenge to the dealer and independent maintenance organizations.
- Communications industry applications lead the way.
- Communications industry will have "proved it out."
- Cost and complexity will preclude use of fiber optic control bus. From a performance point of view it is not required.
- Fiber optic input/output devices must decrease in cost before this technology will become popular.
- Fiber optic technology will take a while to become practical.
- I expect rapid growth in fiber optic use after 2000 but it will be a slow start.
- We may have low volume systems by then.
- One can speculate that it will be all fiber optic; it depends on how the "system" is managed.

MANUFACTURER/SUPPLIER COMPARISON

The Delphi VI OEM and supplier panelists provided identical forecasts of 10% fiber optic utilization in multiplexed (MPX) systems by the year 2000. Their respective interquartile ranges are also identical at 5% to 10%. As noted in the trend analysis, present forecasts for the year 2000 are substantially lower than previous Delphi forecasts for 1995. Coincidental, with that observation it is of interest, from a historical perspective to note that the manufacturer/supplier comparison from Delphi V revealed a remarkable degree of disagreement between the two panelists groups regarding the percent utilization of specific MPX systems. In that survey the OEM panelists forecast that only 10% of MPX systems would utilize a fiber optic control bus and that 90% would utilize a wire control bus. The supplier panelists, however, forecast a 50-50 breakout between fiber optic and wire control.

TREND FROM PREVIOUS DELPHI SURVEYS

The panelists participating in Delphi IV and Delphi V were asked what percentage of multiplexed systems would utilize fiber optic control buses by 1995. At that time, the forecast by Delphi IV panelists was 21%; the Delphi V panelists forecasted 25%.

STRATEGIC CONSIDERATIONS

In Delphi VI, expectations for fiber optic based multiplexed systems in the year 2000 are less than those of Delphi V. Perhaps this reduced enthusiasm is due to continuing cost problems and the important challenge of providing absolutely trouble free interfaces between electrical and optical components in a vehicle environment. It must be recognized that the creative and innovative skills of the electronics industry may, literally, at any moment, deliver a technology that could completely change the expectation of our panelists. The incentive for fiber optics appears to remain strong.

TECH-79. What percentage of NAPPVs will employ the following electronic/electrical features in 1995 and 2000?

Electronic/Electrical Features	Forecast Features by 1995 and 2000			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Cruise control	70%	90%	50/80%	70/95%
Cellular phones	10	25	10/15	20/40
Electronic key entry	10	25	10/15	20/40
On-board diagnostic via expert systems (AI)	5	15	2/5	10/20
Drive-by-wire (electronic throttle control)	2	10	1/5	5/10
CRT touch screens	1	3	1/2	2/5
Voice activated/interactive controls	1	2	0/1	1/3
Facsimile	1	2	1/2	2/5
Personal computers	1	2	1/1	2/5
Steer-by-wire	0	0	0/1	0/5

SELECTED EDITED COMMENTS

- Cellular phones will be pervasive, but will remain to a large degree dealer or aftermarket installed. OEM will provide pre-wire option.
- CRT for navigation option only. Liability concerns will limit steer-by-wire.
- Diagnostics is limited only to available computer technology at a reasonable cost.
- Fax and PCs will remain personal items carried by the individual, not car installed. Voice interactive information systems are likely; use for traditional controls is less likely. The narrow focus of most diagnostic regulations (California Air Resources Board and EPA) will limit the automaker's flexibility in powertrain diagnostics. Some growth is expected in body and chassis diagnostics.
- Portable computers will become more competitive in price. Electronic throttle control must overcome liability concerns but is essential part of meeting higher CAFE and/or future IVHS-type collision avoidance intervention. Electric cars will all be "drive-by-wire." Keyless systems will be much more popular, but only cost justified in luxury priced vehicles. Fault recorder and off-board area AI more practical. Voice activated/interactive controls are not cost effective.

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists' forecast for the majority of electronic features are essentially identical. Two minor exceptions are forecasts for drive-by-wire (1995) OEM = 2%, suppliers = 1%; electronic key entry (2000) OEMs = 20% and suppliers = 25%.

TRENDS FROM PREVIOUS DELPHI SURVEYS

As is apparent in the following table, the dramatic reduction in forecast application of electronic/electrical features from Delphi IV forecast to Delphi V continues. Although there is a modest increase in such features as electronic key entry and cellular phones, overall market penetration gains are either negligible or nonexistent. Long-term consumer enthusiasm, cost reduction factors, and fundamental "retro-tech" philosophy appear to have dramatically influenced the level of application of many electronic/electrical vehicle features.

Electronic Features	Forecast Usage by 1995			Forecast Usage by 2000	
	1987 Delphi IV	1989 Delphi V	1991 Delphi VI	1989 Delphi V	1991 Delphi VI
Voice-interactive controls	10%	1%	1%	2%	2%
Drive-by-wire	5	1	2	5	10
Steer-by-wire	N.A.	0	0	1	0
Electronic key entry	15	5	10	15	25
Cellular phones	15	5	10*	15	25*
CRT touch screens	5	2	1	5	3

N.A. = not asked

* See TECH-79

STRATEGIC CONSIDERATIONS

A host of vehicle features were addressed in this question to ascertain expectations for their application during the next ten years. In some cases, the forecasts for components (such as cruise control) are high, suggesting almost a standardization by the year 2000. There is significant support for rapid growth in both cellular phones and electronic key entry; and there are modest expectations for on-board diagnostic systems based on artificial intelligence and even the use of electronic throttle control (drive-by-wire). On the other hand there is little support for CRT touch screens and voice-activated controls. Steer-by-wire received no support at the median although there are minimal expectations at the upper quartile for this technology

The expectation for expansion of these technologies during the 1990s is consistent with the overall forecast growth of automotive electronics. It would appear that electric/electronic-based component suppliers will experience significant growth for the foreseeable future. In most cases, the extent of application of the various technologies will be dependent on market forces and how effectively both manufacturers and suppliers do their jobs. Furthermore, any number of emerging technologies could change these forecasts rather significantly, as the tremendous creativity of the electronics industry is focused on these automotive applications.

TECH-80. Do you expect that vehicle electrical-system voltages will be increased over the 12-volt level by the year 2000? If yes, what voltage level do you expect by the year 2000?

Forecast of Electrical System Voltage Increase	
Yes: 78%	No: 22%

Voltage Level (percent of responses)		
24V: 25%	36V: 2%	48V: 10%
12/24V: 30%	12/36V: 3%	12/48V: 30%

SELECTED EDITED COMMENTS

- Expect 12/24V to be introduced by 2000 on some low volume production vehicles.
- Twelve/twenty-four volt is best guess but 12/48V is a real possibility.
- Twelve-volt systems will have to be maintained to control the cost of transition to higher voltage. Also, low cost power supplies make it possible to provide 12V without battery taps or multiple batteries. The push for higher voltage will be driven by the need for energy efficiency--direct electrical and indirect mass savings.
- Change is much more important than the voltage we change to.
- Consider multiplexing and the use of optical (plastic) fiber communication. Consider passenger vehicles evolving toward primary offices; the parking structure is the "office building" with "connections" (quick ones) to power, HVAC, and information networks.
- Dual voltage systems are the most likely.
- Higher voltage electrical systems cannot be incorporated by 2000, however, probably by 2005. Forty-eight volts would be most advantageous.
- Higher voltage will be for specific options such as heated windshields.
- Obtain the efficiency of 48V and use 12V for powering regulated electronic supply voltage.
- Penetration will be limited. If you need high electrical power, you will not meet CAFE, hence the need for 48V is limited.

MANUFACTURER/SUPPLIER COMPARISON

While a large percentage of the OEM panelists (83%, versus 70% of suppliers) forecast that voltage levels would increase by the year 2000, they appear to be in general accord on single-system voltage levels. There is a significant degree of disagreement regarding dual voltage levels. As indicated in the following table, there is some disparity among the two groups of panelists regarding what they consider the electric systems voltage levels will be by the year 2000.

Voltage Level: (percent of responses)					
Manufacturer			Supplier		
24V: 23%	36V: 3%	48V: 10%	24V: 28%	36V: 0%	48V: 11%
12/24V: 39%	12/36V: 5%	12/48V: 20%	12/24V: 14%	12/36V: 0%	12/48V: 47%

TREND FROM PREVIOUS DELPHI SURVEYS

In Delphi V, slightly over one-half (58%) of the panelists forecast an increase in vehicle electrical system voltage by the year 2000. The Delphi V panelists also forecast that the voltage level would be 24 volts.

STRATEGIC CONSIDERATIONS

Since Delphi V, our panelists have been suggesting a significant increase in expectations for electrical systems that are greater than 12 volts (or at least systems with part higher voltage that maintain 12 volts for some functions). At this point, there is no clear consensus as to the preferred system, although we suspect that this will begin to emerge in the next few years. This higher voltage strategy is obviously dictated by the much higher electrical power requirements of new vehicle functions. This could lead to some significant economies in such areas as the wiring harness and overall charging system.

Many panelists believe that a 12-volt circuit will still be desirable, particularly for lighting. It is interesting to note the comment that stated that the change itself may be more important to the industry than the new voltage levels.

Another interesting issue was raised with regard to fuel economy requirements. Greater electrical loads mean higher fuel consumption, which could be of increasing concern if the future CAFE standards are increased significantly.

The voltage issue is of significant importance to suppliers of electrical and electronic componentry and battery suppliers. Increased overall electrical loads may lead to using more than one battery, which could have a major impact on the battery suppliers for both new vehicles and the replacement market. This would be of far greater significance for battery producers than modest numbers of electric or hybrid vehicles. In any event, developments in the system-voltage area must be watched very closely, and suppliers should be advised to monitor various standards activities such as those within the Society of Automotive Engineers, to ensure that they remain on track with the specific actions of the manufacturers.

In light of the foregoing, we conclude that the electrical system is likely to be an area where significant changes will occur in the decade ahead.

TECH-81. What will be the number of rotating and linear electric motors in standard and upscale NAPPVs in 1995 and 2000? (Please provide your estimate for current vehicles.)

Vehicle Types	Average Number Electric Motors					
	Median Response			Interquartile Range		
	Current Est.	1995	2000	Current Est.	1995	2000
Standard NAPPV	7	10	12	5/8	10/12	12/15
Upscale NAPPV	15	20	25	12/17	20/23	23/35

SELECTED EDITED COMMENTS

- "Standard" vehicles will tend to have more content (responding to customer demand) and the number of motors will increase. Tougher emissions regulations will also add components with motors (electric air pumps, linear motors, etc.).

MANUFACTURER/SUPPLIER COMPARISON

The manufacturer and supplier panelists present similar forecasts for electric motor utilization for both 1995 and 2000.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

One measure of the growing role of electrical/electronic functions in future vehicles is the number of electrical motors (either of a linear or rotating type) expected in future vehicles. We addressed both for a "standard" vehicle and an "upscale" vehicle with a significantly greater feature content. For both vehicles, significant increases in the average numbers of motors are forecast and the quartile range is surprisingly narrow, suggesting relatively strong consensus within the industry. It appears that significant progress has been made in motor technology with better magnetic materials and improved design and production processes. This process is further supported by what seems to be an insatiable consumer demand for more features.

It will certainly be interesting to see how such factors as possibly tough, future fuel-economy standards will impact overall feature content and the use of the various motors types. They represent an increased electrical load on the vehicle and therefore a reduction, to some extent, of fuel economy. Of course, there is a "flip" side to this argument as noted in the comment above.

TECH-82. What are the most likely Intelligent Vehicle Highway System (IVHS) technologies that will be commercially feasible and/or incorporated by NAPPVs by 2000?

Panelists responding to this question often used different terminologies to describe essentially the same IVHS technology. Therefore, some IVHS technologies may be interrelated or overlapping. The following categories are meant to provide as much specificity of responses as possible. Each category is followed by a definition of that category.

Most of the panelists gave multiple responses. Therefore, ranking is given as responses per percentage of panelists.

IVHS Category	Percent of Respondents
Local Information Systems by 2000 Motorist Service Information (**MSI**) A traffic control center sends information to drivers via radio and beacons. Drivers receive information on traffic, local weather, road conditions, accidents, etc. CB radio systems may be included.	60%
Automatic Tolls and Road Pricing (**ATRP**) These systems assess and debit user fees for a variety of road services including road usage and parking.	4
Collision Warning (**CW**) Advance sensors warn drivers about road and vehicle obstacles.	8
Geographical Systems by 2000 Cooperative Route Guidance (**CRG**) These systems establish communication between roadside traffic computers/sensors and on-board computers, sensors, and displays. Positional information is provided to the driver. These systems may include digital maps and other information formats. "Ali-Scout" and other systems of this type are included.	52
Vehicle Location and Identification (**VLI**) These systems typically use passive transporters on the vehicle, which are automatically integrated at stations located along the highway. This may include on-board computers for location control and continuous monitoring with Loran C.	36
Autonomous Vehicle Navigation (**AVN**) This system provides the driver with static information on vehicle location relative to a stored map of the road network. Other information formats such as listing of directions may be included. ETAK and other systems of this type fall into this category.	24
Backup Systems by 2000 Speed and Headway Keeping (**SHK**) This system senses distance between vehicles and automatically adjusts speed to keep a safe distance between vehicles. This is similar to the station-keeping/cruise control concept. It may also include interactive speed limits.	24
Collision Avoidance (**CA**) This is a system of sensors and an on-board computer, which predicts a pending collision and automatically exercises steering or braking controls to prevent a collision from occurring.	4
Continuous Control Systems by 2000 Automated Highway Chauffeuring (**AHC**) Information about road, traffic, and vehicle is provided to servos that control vehicle steering, braking, and acceleration. The vehicle is automatically guided independent of physical guideways.	16
None to very little by 2000	8

REPRESENTATIVE RESPONSES

- Front/rear collision avoidance "radar"; blind spot warning "radar"; automotive toll collection. Navigation and routing aids. Cruise control could be considered pre-IVHS technology and could be integrated with radar for front/rear collision avoidance and "station" keeping in car pool lanes or platoons.
- Route guidance; map matching, infrared beacons. Navigation: GPS, map matching, electronic compass. Traffic management headway control: radar or IR range control combined with automotive braking.
- Satellite navigation, local area maps or CD for ROM packages. Automatic route guidance using traffic information, congestion, etc., is unlikely to be significant, as standards are not yet set.
- Navigation aids tied to route guidance; highway/traffic information to driver via radio and programmable signals; crash warning systems and simple automated headway controls.
- None, too expensive. The nation's highway infrastructure could not be adapted by 2000.

STRATEGIC CONSIDERATIONS

There appears to be general consensus that IVHS will be an important systems-based technology of the future, which will definitely impact future vehicles and the driving environment. However, at this stage of IVHS development, it is very difficult to forecast specific areas of impact on future vehicles. In addition to certain general observations that are evident in the responses, panelists foresee better information systems and geographically based guidance by the year 2000. There is even reasonable support for location, vehicle identification, and other characteristics that may be considered within the rubric of IVHS technology. In our judgement, this continues to be a very important area of future technology which has the potential to bring rather fundamental change to future vehicles. However, at this point, it is far too early to make specific forecasts with a high degree of reliability. We would certainly urge all manufacturers and suppliers to at least participate in a peripheral way in the broadening discussions on IVHS technologies. There is no clear direction yet to justify major investment, but key directions could begin to emerge within the next few years. This could mean important new opportunities, as well as areas where existing technologies are challenged by new thinking. Here at the University of Michigan we have an outstanding group deeply involved in IVHS-based technologies. We urge any reader with a potential interest to contact our Office.

TECH-83. What percentage of NAPPVs will utilize the following Intelligent Vehicle Highway System (IVHS) technologies by the year 2000?

IVHS Category	% NAPPVs by Year 2000	
	Median Response	Interquartile Range
Motorist service information (MSI)	40%	10/60%
Cooperative route guidance (CRG)	15	5/30
Vehicle location and identification (VLI)	10	5/20
Autonomous vehicle navigation (AVN)	10	5/20
Speed and headway keeping (SHK)	10	2/20
Collision avoidance (CA)	0	0/5
Automated highway chauffeuring (AHC)	2	0/5

SELECTED EDITED COMMENTS

- A passive collision avoidance system providing warning only is more likely. Active collision avoidance will be political but too prone to legal problems (e.g., drivers claiming that avoidance action was incorrect).
- The cost of installing and maintaining the system is prohibitively high. I would like to see a lot of these features implemented, but we can not afford to repair the existing bridges and highways. How can we afford IVHS?
- These are estimates for OEM systems only. The dealer/aftermarket usage may be higher. The legal system will prevent collision avoidance technology from being applied--warning type systems may appear.
- Vehicle location and identification will be heavily used by fleet operations (i.e., trucking, local delivery, maybe rental cars) and emergency vehicles (i.e., police, fire, ambulance) but would be considered invasion of privacy for private vehicles. Speed and headway keeping is an outstanding way to improve safety and is somewhat easily implemented; but it requires drive-by-wire type technology, which will be limited by liability concerns, and it interferes with driver's control independence. Systems that just warn the driver will be more prevalent. Collision avoidance infrastructure is too expensive and, again, raises the liability question.
- VLI use will be dependent upon deployment of related infrastructure components.

MANUFACTURER/SUPPLIER COMPARISONS

As the following table indicates, the OEM forecasts are more enthusiastic regarding the use of the described IVHS systems in NAPPVs by the year 2000 than are the supplier panelists.

IVHS Category	% NAPPVs by Year 2000	
	Manufacturer	Supplier
Motorist service information (MSI)	50%	30%
Cooperative route guidance (CRG)	15	10
Vehicle location and identification (VLI)	15	5
Autonomous vehicle navigation (AVN)	15	10
Speed and headway keeping (SHK)	10	10
Collision avoidance (CA)	0	0.1
Automated highway chauffeuring (AHC)	1	1

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

In this question we addressed a few specific IVHS technologies, although some can be considered quite independent from the much broader and comprehensive IVHS field. By the year 2000, significant application of motorist service information is suggested as is modest support for a wide range of technologies, including route guidance, vehicle location and identification, vehicle navigation, and speed and highway keeping. The quartile range is broad, indicating a high level of uncertainty with regard to all of these technologies. This field bears careful watching by all associated with the industry, particularly those in the electronics industry. Our personal view is that some of these areas could accelerate rapidly with technological breakthroughs and customer demand, particularly in fleet operations.

TECH-84. What percentage of NAPPVs will be equipped with the following electric motor driven devices by the years 1995 and 2000?

Electric Motor Driven:	Percent NAPPVs			
	Median Response		Interquartile Range	
	1995	2000	1995	2000
Water pump	0.5%	3%	0/1%	0/10%
Oil pump	0	0	0/1	0/5
A/C compressor	0	5	0/1	0/10
Air pump	3	10	1/10	2/29

SELECTED EDITED COMMENTS

- Charging and recovery of electrical power is too inefficient. Direct drive from engine is most efficient.
- Engine driven devices are more fuel efficient than electric-motor driven.
- Applications will occur only for electric or hybrid vehicles, which will be negligible.
- This depends on development and use of more efficient alternators. With that, the benefits, and therefore usage of electric-driven accessories could be substantial.
- Which air pump, the emissions, or vacuum drive? Applications depend on a total review of the vehicle accessory system. These accessories need a new type of alternator for fuel efficiency reasons.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

Because of increased expectations for electric motors, we decided to consider some fairly significant components that presently use other drive mechanisms as candidates for electric motors. In most cases the expectations are rather low. Although in the case of water pumps, air conditioning compressor, and air pump, expectations are modest for future use. The interquartile range in all of the forecasts is extremely broad, however. It will certainly be interesting to see the cost and packaging implications of electric motors and also their impact on fuel economy. It would seem likely that with more precise control capability of motors, energy consumption might be reduced enough to warrant more serious consideration, particularly as tougher CAFE standards emerge.

TECH-85. What new electronic noise cancellation technologies will be utilized in NAPPVs for the management of (1) interior compartment noise, and (2) exhaust noise by the year 2000?

Technologies	% NAPPVs by year 2000	
	Median Response	Interquartile Range
Electronic interior noise cancellation		
Digital Signal Processing (DSP) systems integrated into audio systems	10%	5/25%
None (not technically or economically viable)	90	80/98
Electronic exhaust noise cancellation		
"Electronic" muffler	10	5/30
None	90	70/98

SELECTED EDITED COMMENTS

- It is not theoretically possible to cancel all frequencies at all parts of the compartment, however localized areas can benefit.
- DPS is probably not a good way to manage interior noise levels--limited applications using vehicle audio system to manage low frequency problems.
- These may be offered on a low volume of speciality vehicles but I do not expect wide acceptance because of limited effectiveness.
- DSP will be offered in high line vehicles as a premium/concert sound audio system option. The electronic muffler will be highly desired for CAFE and emissions help but development (and hence application) will be slowed by severity of exhaust system environment.
- Maybe an adjustable muffler for "sporty-roar" to "quiet-cruise" performance. Otherwise, the only possible benefit is better efficiency (less back pressure). This is far off.

MANUFACTURER/SUPPLIER COMPARISON

The OEM panelists forecast a significantly greater utilization of noise cancellation technologies than do the supplier panelists. For the year 2000, the OEM panelists forecast a 10% penetration for electronic interior-noise cancellation and a 20% penetration for electronic exhaust-noise cancellation. The supplier panelists forecast a 5% penetration for both groups of technologies.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATIONS

In the past several years, a potentially important new technology, electronic noise management, has begun to receive attention. At this point our panelists do not view these technologies as ready for high-volume application. Still, there is sufficient interest to suggest that developments should be watched rather closely. Interior-noise cancellation may use already existing, but modified, interior audio systems as noted in the comments.

One potential advantage of an electronic muffler is the possible reduction in back pressure which could have a positive impact on fuel economy and exhaust emissions. This is likely to be a technology that will appear first in luxury and highly specialized vehicles. The experience of applying this technology and cost reduction associated with high-volume economies of scale may result in increased use in the future. Clearly, creation and innovation are necessary if these technologies are to become a reality.

X. AFTERMARKET/DEALERS' SERVICE

TECH-86. What percentage of the following automotive services will be performed by aftermarket independent/franchise service centers, and what percent by dealerships, in the years 1995 and 2000?

Automotive Repair Service	Percent of Automotive Service							
	Median Response				Interquartile Range			
	Dealership		Aftermarket		Dealership		Aftermarket	
	1995	2000	1995	2000	1995	2000	1995	2000
Electrical/electronic	80%	80%	20%	20%	60/90%	70/90%	10/40%	10/30%
Mechanical	50	55	45	40	40/70	35/70	30/60	30/60
Total percent of auto service	55	60	40	40	40/70	40/70	30/60	30/60

SELECTED EDITED COMMENTS

- The aftermarket service is due to decrease as system complexity increases. Aftermarket service centers will perform only routine maintenance, but will lose out as required service decreases. Dealers need to improve the image of the abilities and convenience of their service departments.
- Complexity will drive the little guy out of business.
- This depends on how well each serves the customer. It is possible the auto manufacturer will take on a complete prepaid maintenance responsibility, in which the percentage for cars covered would approach 100%.
- Do-it-yourself service is becoming more difficult as electronics become more integrated and complex. Likewise, independent service facilities will also suffer.
- I see an increase in dealer service as diagnostics get better and customer satisfaction increases.
- Special diagnostics will move more service to dealerships.
- Unnecessary, complicated electronics will kill the aftermarket. Extended warranties will shift work to dealers.

MANUFACTURER/SUPPLIER COMPARISON

The two panels are in general agreement on this question.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATION

The competition between traditional dealer service and the aftermarket is highlighted by this question. While the balance between the service sectors is expected to be maintained for mechanical functions, this is certainly not the case for electrical/electronic service. Considering the dramatic increase in the role of automotive electronics and the expanded use of electrically-based features (even as mechanical service requirements are lessening), it seems clear that dealership service is likely to be the big winner during this decade. Furthermore, with the generally shrinking total aftermarket (as a result of improved quality, durability, and reliability of automotive components), there may not be enough business for everyone in the service or service-parts business.

However, the future success of any service organization will fundamentally be based on how well the customer is served. Customer satisfaction is the dominant success factor today. If you provide it, you win. If you do not, you lose.

TECH-87. Indicate your view of the following opportunities (where 1=significant opportunity and 5=little opportunity) for dealers and aftermarket centers. Please exclude the "do-it-yourself" market.

Aftermarket Opportunities	Ranking
Cellular phone installation	1.8
Expanded electrical/mechanical diagnostic repair centers	2.1
Entertainment systems installation	2.7
Establishment of electronics-module repair, remanufacture, and replacement centers	2.7
Material body appearance modifications/customization/styling enhancements	2.9
Service contracts	2.9

SELECTED EDITED COMMENTS

- There will be less routine maintenance required in the future.
- Antitheft systems installation is a significant opportunity.
- Technical training skills will be key to many of these ideas.
- Dealer-installed options (wheels, trim, conventional items) is a significant opportunity.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TRENDS FROM PREVIOUS DELPHI SURVEYS

In Delphi V the panelists were asked to project major new opportunities for the aftermarket sales and service industries. While the present ranks opportunities for both dealer and aftermarket, the separate aftermarket opportunities rankings are in accord with the present data and worthy of consideration. In Delphi V the establishment of electronics repair, remanufacture and replacement centers and expanded electrical/mechanical diagnostic and repair centers was ranked as the greatest opportunity. Entertainment system installation was the next highest ranking opportunity. This corresponds very favorably with the current rankings. Opportunities for service contracts and body appearance modifications/enhancements received substantially less of an endorsement from the Delphi V panelists. Again, this is in accord with the rankings presented by the current Delphi panelists.

STRATEGIC CONSIDERATION

The battle between independent aftermarket and dealers' service operations is expected to be heated in the years ahead. In most cases, independent service outlets will probably fade in importance due to more sophisticated electronic technology, improved component durability, and longer warranty periods, which favor traditional dealer service. However, there will still be a significant non-dealer service business, particularly in some areas. Certainly this would appear to be the case with regard to many of the categories suggested in this question. Cellular-phone installation is expected to continue to offer a significant aftermarket opportunity, as is expanded electrical/mechanical diagnostic work. However, the dealer will undoubtedly be doing an increasing fraction of the more sophisticated diagnoses. The remaining categories of service are all expected to provide business for independent outlets. Other areas, such as the antitheft system, as suggested in the comments, should perhaps be considered in this discussion as well.

While the results of this question are certainly not conclusive, they do suggest that the non-dealer service business will remain an important part of the automotive service industry. However, by no means is it expected to be considered an automatic winner in the competition with the traditional dealer body. Generally, we expect that dealers will apply increasing pressure to the manufacturers to provide them more exclusive service and support opportunities at the expense of others. Furthermore, this all must be viewed in the context of what would appear to be an overall shrinking aftermarket because of changes being made in vehicle technology.

XI. OTHER ISSUES

TECH-88. What do you believe that the U.S. Congress should do, or should not do, to assist the traditional, domestic automotive industry?

The U.S. Congress should:	Percent Responding
Establish "fair" trade policies. This includes import restrictions (quotas), local content, "anti-dumping", equivalent taxes, etc.	30%
Permit cooperative R&D efforts with government partnership and/or sponsorship.	22
Develop a national manufacturing/industrial policy.	17
Relax legislated regulations, develop legislation based on technical realities.	12
Develop appropriate fiscal policy to encourage investment and R&D. This includes tax credits and/or accruals for R&D, product design, etc.	10
Increase gas taxes to reduce consumption and repair highway infrastructure.	6
Develop a national energy policy.	4

Other suggestions include: revamp the health care system, encourage the development and use of alternate fuel vehicles, provide tax incentives for fuel efficiency, and mandate safety items such as air bags and ABS.

REPRESENTATIVE RESPONSES: U.S. Congress **should**

- Provide a complete, all encompassing study of value added/cost for each new regulation proposed. Should push extremely hard for true "free trade."
- Allow joint research and development in non-competitive areas, e.g., air bags. Heavy pressure on Japanese for immediate results on import restrictions.
- Develop an industrial policy that identifies a government-industry relationship which will hasten a globally competitive position.
- Pursue fair trade agreements because they are key. Long term energy policy and environmental policy needs to be developed jointly with industry. Strategies to achieve would then follow.
- Get all state and federal agencies to develop "cycle plan" of integrated (emissions, safety, etc.) regulations.

The U.S. Congress should not:	Percent Responding
Legislate regulations/requirements that are not technically feasible or are only politically expedient.	68%
Should not restrict market share of imports/quotas by protectionist legislation.	15
Should not allow unrestricted access to U.S. market or tolerate "unfair" trade practices.	12
Should not fund technologies that industry does not need or want.	5

DISCUSSION

Fifty-seven percent of the panelists indicating that Congress should not legislate regulations that are not technically feasible specifically identified CAFE standards.

REPRESENTATIVE RESPONSES: U.S. Congress **should not**

- Impose emissions regulations that are politically expedient but scientifically (or logically) flawed; includes CAFE standards that are not economically practical.
- Impose undeveloped technology for vehicle requirements.
- Should not do anything to damage "free trade."
- Should not keep threatening U.S. companies with shutdowns based on inability to conform regulation.
- Unilaterally implement regulations without discussing implications with the industry (i.e., make it a cooperative effort). Stop believing that the Japanese trade fairly.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

COMPARISON OF FORECASTS: MAT-12

The Technology and Materials panelists are in agreement that the U.S. Congress should do more in the adjudication of "fair" trade policies and make an effort to establish some type of national policy regarding U.S. industrial development, including a closer governmental cooperation or partnership.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATION

Our panelists generally had a lot to say about the role of the U.S. Congress, and perhaps government in general, in relation to the automotive industry. Generally, panelists believe that Congress should work to establish fair trade policies, encourage cooperative research and development efforts within the industry, develop an overall national manufacturing policy, balance regulation with technical realities, and act more fiscally responsible in terms of overall legislative activity. In a general sense, what can be inferred is that government should take more of a systems approach to policy formulation. We have left behind the time when there was relatively little threat from external or international competition. For example, antitrust action traditionally sought to weaken strong companies in competition with a weak company. Today's competitive environment requires just the opposite: the strengthening of the weak to bring them to the level of the strong.

This is a particularly important issue with the important international problems that abound in the industry today. Congress, in its desire to help, should formulate all policy considering the context of the present, global, competitive environment.

The panelists note that they are particularly concerned about regulations that are not technically feasible but politically expedient. One particular standard that received almost universal scorn from the panelists is CAFE which, indeed, seems to be out of step with the realities of a world moving toward market-oriented economies. Unless our government begins to adopt a more systems-oriented policy agenda based on a more complete understanding of the industry and the demands of society North American industrial survival may be at risk. In fact, at the present time, we are concerned with the very survival of this industry. It is in an extraordinarily fragile state, and only through good management and wise government policy can it be assured of long-term success.

TECH-89. There is increasing concern regarding the availability of critical skills needed within the automotive industry. Please indicate, the skill areas where you believe problems or deficiencies exist at the present time and/or will develop within the next decade?

Critical Skill Deficiencies	Responses Panelists
Need for increase in engineering/technical expertise and skilled trades	85%

Within this category certain engineering disciplines and functions were specified. Those receiving significant citation are presented below as percentage of responses within that category.

Category	Percentage of Responding Panelists
Discipline	
Electrical engineering	38%
Manufacturing/process engineering	17
Design/product engineering	15
Materials engineering	12
Unspecified	18
Function	
Improved vehicle design and development	28%
Development of engineering software	11
Increase in management expertise	4
No improvement necessary	1

DISCUSSION

This question received one of the highest response rates in the Technology Delphi. The categories reflect a generalization of responses and should not be considered exclusive.

REPRESENTATIVE RESPONSES

- All engineers and designers. Electrical/electronic engineers and technicians. Control systems engineers. Service technicians.
- Dealer service technicians. Engineers in general for product and process; CAD designers; outstanding wholesale and retail salesforce.
- Need engineers with total vehicle/system expertise. Important to have maintenance technicians distributed around the country and skilled technicians and engineers for manufacturing plants.
- I believe there is a reasonable supply of needed skills especially now that there is a business depression. However, we do face a real shortage of engineers in future years.
- Multidisciplinary engineers for engine and powertrain. As controls become more complex and we go to 32 bit ECMs we must have auto engineers that are also computer and control systems design capable. Also need technical writers.

MANUFACTURER/SUPPLIER COMPARISON

These comparisons are not made for open-ended questions.

TREND FROM PREVIOUS DELPHI SURVEYS

This question was not asked in a previous Delphi.

STRATEGIC CONSIDERATION

It is becoming increasingly clear that the automotive industry, both at the national and international levels, will experience shortages of critically skilled human resources in the decade ahead. Present economic conditions tend to mask the significance of this growing problem. The panelists, as indicated by the voluminous responses, were extraordinarily interested in this question. In terms of discipline, electrical engineers received the strongest response, followed by manufacturing and process engineers, and then design/product engineers.

In terms of function, improved vehicle design and development engineers registered the greatest support followed by software development engineers. We sincerely believe that "profound knowledge" will be a critical competitive factor in the 1990s, and an organization will only gain this knowledge through competency of its own employees or through relationships with other organizations. Effective management of knowledge and knowledge-based personnel is essential.

A review of the various comments reveals strong support for a systems-engineering capability. Systems engineers regularly cross boundaries and link various elements of the vehicle together. They always consider the whole, even as they deal with details. Systems engineering generally captures or includes many disciplines and functions considered to be part of automotive engineering.

DEFINITION OF TERMS

CAPTIVE IMPORT. A vehicle built outside of the U.S. and Canada and which is sold through a traditional domestic dealer franchise (i.e., Dodge Colt).

CAPTIVE TRANSPLANT. A vehicle built inside the U.S. or Canada in a plant managed or owned by a foreign corporation and sold through a traditional domestic dealer franchise (i.e., Ford Probe).

IMPORT. Refers to all vehicles manufactured outside of the U.S. or Canada regardless of distribution channel used (i.e., forecasts should include vehicles such as Ford Tracer).

NAPPV. North American-Produced Passenger Vehicle.

OEM. Original Equipment Manufacturer.

RESKINNING. A minor facelift of a vehicle which does not require new safety, fuel economy, or emissions re-certification.

TRADITIONAL AMERICAN MANUFACTURER. Refers to all U.S.-headquartered (parent company) manufacturers or dealership networks regardless of production location (i.e., forecast for General Motors should include NUMMI-produced Novas and imported Spectrums).

TRADITIONAL IMPORT. Refers to all non-U.S.-headquartered vehicle manufacturers or dealership networks regardless of production location (i.e., Honda's U.S. production should be combined with their import vehicles).

TRANSACTION PRICE. The total cost of a vehicle to the customer including all factory-and dealer-installed options, taxes, and delivery charges.

TRANSPLANT. A vehicle built in the U.S. or Canada in a plant managed or owned by a foreign manufacturer.

INDEX OF TECHNOLOGY QUESTIONS LISTED BY TOPIC